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THE UTILIZATION OF ALUMINUM IN THE ARTS.*

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Until the present decade, the attention and research of everyone interested in the metal aluminum were directed almost exclusively to problems connected with the cheap production of the metal by means more adapted for large commercial operations than by the processes by which it had previously been manufactured.

The prevailing and popular opinion had been that if anyone should be fortunate and skilful enough to produce aluminum so cheaply that it could be sold at a profit at the price of a dollar per pound, the consumption of the metal would become enormous; and if it could only be sold at the price of 50 cents

*A lecture delivered before the Franklin Institute, March 26, 1897.

per pound—a price which, taking its relative specific gravity into account, would nearly approach that of copper and brass —the demand for the metal would be prodigious, and the profits which would accrue to the manufacturers would be of such fabulous amounts as simply to take one's breath away to attempt to estimate them.

Much of this sort of speculation has it been my lot to hear, and, I may truthfully say, to endure, from inventors of processes for the manufacture of aluminum (in my investigation as to their relative values), which have since proved to be either chemically impossible or commercially impracticable.

Early in the progress of the Pittsburgh Reduction Company in the manufacture of aluminum, working with the Hall process, I had my attention sternly called by the necessities of the case to the fact, which further and larger experience has simply verified, that the problems connected with the promotion of the sale of aluminum, its adaptability for various purposes, and the utilization of the metal and its alloys in the arts, were as difficult of solution as the problem of cheapening the processes for its production, and required as much research; offering a great many more opportunities for remuneration than would the search for cheaper modes of production.

The exploiting on a considerable commercial scale and the perfecting of the details of the Hall process, as carried on by the Pittsburgh Reduction Company at its several works at Niagara Falls, N. Y., and New Kensington, Westmoreland County, Pa., have already permitted the selling price for aluminum in large quantities to be placed much below the relative price for copper and somewhat below the relative price for brass.

Aluminum is now selling in large quantities at 31 and 32 cents per pound, in ingots; and the relative increase in price for sheets, plates and bars, over the price for ingots, is not greater than that charged for either of the metals copper or brass.

Copper sheet, according to the Official Copper Manufacturers' price-lists, has a specific gravity of 8·93, and brass sheet varies (as it does also in composition) from 8·15 to 8·20 specific gravity. Aluminum sheet runs from 2·62 to 2·66 specific

gravity. On the basis of their specific gravities, copper can be reckoned as being 3·3 times heavier and brass 3·15 times heavier than similar sections of aluminum.

The consumption of the common metals in the United States during 1895 was as follows:

	Short Tons.
Copper	156,000
Brass	60,000
Zinc	89,686
Lead	161,440
Tin	27,126
Nickel	375

The output of aluminum in the United States during 1896, which was practically all consumed within that period, was only about 1,300,000 pounds; and the output for the year 1897 will be about 2,000 tons, and of this, I estimate a consumption of only about 1,000 net tons in the United States.

While the partial replacement of brass by aluminum will undoubtedly take place, in accordance with the law of the "survival of the fittest," nevertheless, so great is the conservatism of tradespeople, that it will be only slowly that its relative merits and relative cheapness will win for aluminum its eventual position in importance as compared with the other common metals of large tonnage consumption, such as copper, brass, zinc, tin and lead. It has already met and outdistanced nickel in the amount of its consumption.

While the output of less than 2,000 tons of aluminum, in the year 1897, is very small as compared with the consumption of 156,000 tons of copper and 60,000 tons of brass during the year 1895, in the United States, and while it is a fact that aluminum is now offered at prices considerably lower than copper for any given purpose, and fully as low as brass in many cases, nevertheless, the Pittsburgh Reduction Company will be quite satisfied if its entire output for the present year is taken by the trade.

In a general way, the uses of aluminum have enlarged very much during the past eight years; and, from a consumption, in 1889, of not over 100 pounds of aluminum per annum in the United States (selling at not less than $8 per pound), the

metal has pushed its way to the front to a consumption of over 600 tons in the year 1896. This lecture is given to outline in a general way the uses that have thus far been suggested for aluminum, and to give some account of properties of the metal and its alloys which have caused its demand in the arts.

As one of the most important uses of *aluminum* has been its utilization *in the manufacture of steel ingots and steel castings*, I think it well to commence with this special use of the metal.

Many attempts have been made to alloy aluminum in various proportions with iron and steel; but thus far no very satisfactory results regarding its use in iron have been obtained.

The influence of aluminum seems to be as a softener, rather than a hardener, for iron; and the more common use of alloying metals, as hardeners with steel, is therefore precluded in this case.

Aluminum combines with iron in all proportions, but an alloy of 50 per cent. aluminum and 50 per cent. iron, while casting into a solid mass, in a short time will crumble into a powder.

Aluminum is largely used in the manufacture of steel, the amount of aluminum used, however, being comparatively very small and varying with the grade of steel being made, the amount of occluded gases, the temperature of the molten metal, the size of the ingots or castings, etc.

In the manufacture of open-hearth steel ingots, the proportion of aluminum used is from 2 to 4, or at most 5 ounces of aluminum to the ton of steel; the aluminum being added in the ladle, as in the case of steel castings, or (with more economy in the use of the aluminum, and in accordance with the general practice in the United States) as the steel is being poured into the ingot moulds or groups of moulds. Until the proper proportion of aluminum to add in any particular grade of steel has been determined experimentally, it is advisable to start with small lots, for instance, with 2 ounces to the ton of steel, increasing to, say, 5 ounces of aluminum per ton, according to the amount which is found necessary, noting the character of the results obtained.

It has been found that Bessemer steel ordinarily requires

from 1 to 3 ounces more aluminum per ton of steel than similar grades of open-hearth steel, in order to have the same effect.

A steel which has become "wild," as it is called by the melters, or oxidized and overheated, requires considerably increased amounts of aluminum over what is used to advantage in ordinary cases.

The special advantages to be gained by the use of aluminum in steel manufacture are as follows:

(1) It increases the soundness of tops of ingots and consequent decrease of scrap and other items of loss, which more than compensates for the cost of the small amount of aluminum added.

(2) It quiets the ebullition in molten steel, thereby allowing the successful pouring of "wild" heats from furnaces, ladles, etc.

(3) It improves the homogeneity of the steel:

(*a*) By preventing oxidation.

(*b*) By that property of aluminum in virtue of which it rapidly permeates the body of the steel, thereby increasing the ease with which other metals will alloy homogeneously with steel.

(*c*) By decreasing the time that steel will remain fluid after being poured into moulds and causing the steel when solidifying to do so more evenly, preventing a central core remaining molten longer than the outside portion of the metal, and in this way stopping the segregation of phosphorus and other impurities in the "mother liquor" of the metal remaining molten the longest.

(4) It increases the tensile strength of steel without decrease of the ductility.

(5) It removes any oxygen or oxides that may be in the steel, the aluminum acting, in the same way as manganese does, as a deoxidizer. Good steel has been made for electrical purposes, using aluminum entirely in the place of manganese, to remove occluded oxygen and oxides from the molten steel and render it malleable.

(6) It renders the steel less liable to oxidation in casting. This is occasioned by preventing the continued exposure of

fresh surfaces of the molten steel in its ebullition in the moulds after pouring.

(7) It permits the production of smoother surfaced castings and ingots of steel than it is possible to obtain without the use of aluminum.

The chief advantage in the use of aluminum in steel is that first named, *i.e.*, increasing the soundness of the tops of steel ingots and decreasing the scrap and other loss; and for this purpose the use of aluminum in the manufacture of steel is now becoming almost universal with the principal steel manufacturers, not only in this country, but also in Europe.

The phenomenon of quieting steel by the use of the very small proportion of aluminum referred to, is a very important and remarkable one.

Steel poured from a ladle into an ingot mould without being treated would ordinarily boil for ten to fifteen minutes before "freezing over" at the top, and when freezing would rise in the moulds for 8 or 10 inches, with ordinary steel of ten-hundredths to twenty-hundredths of one per cent. carbon, unless heavy chills are placed on the tops of the ingots. When aluminum is added, however, the steel will come up to the required level and remain there, freezing over within thirty to forty-five seconds after the last of the steel is poured into the ingot mould.

Comparative results of the use of aluminum in steel can readily be shown by pouring two ingots side by side, from the same ladle of molten steel, one treated with aluminum in the ingot mould and the other not so treated.

There is danger in adding too large a quantity of aluminum to ingot steel, in which case the metal will settle very solidly and will be liable to form deep "pipes" in the ingots. To add just the right proportion of aluminum to the steel requires some experience on the part of the steel manufacturer.

This danger of the piping of the metal is not a serious one in ingot steel if care be taken to determine just the right proportion of aluminum to use, in order to prevent the formation of too many blow-holes at the top of the ingot. With the metal entirely solid—that is, with too much aluminum added

—the shrinkage, due to contraction, will produce pipes, which will occasion a serious amount of crop ends or defective steel at the top of the ingots.

In the case of the manufacture of steel castings, this trouble is not experienced; the problem is simply to get a solid steel casting, and much larger proportions of aluminum are added in castings than in the practice of making steel ingots, the piping, due to shrinkage in the metal, being taken care of in the large "riser" or sinking-head, which is provided for steel castings.

No difficulty has been experienced with the thorough mixing of the aluminum added to steel, as it seems rapidly and uniformly to permeate the metal without any special care being taken in stirring. This property aids in the homogeneous alloying of nickel and other similar metals to steel as well; and steel manufacturers use aluminum in addition to nickel for this purpose.

Mr. R. A. Hadfield, of Sheffield, England, says that the influence of aluminum in steel appears to be like that of silicon, though acting more powerfully. The same writer (who is confirmed by Howe and Osmund) claims that an addition of aluminum does not lower the melting point of steel, *i. e.*, that the critical point is about the same whether aluminum be present or not. It is the aim, however, in adding aluminum to iron or steel, to add just enough to combine with all the oxygen present, but to leave no trace in the ingot or casting; any more than this is not required.

Mr. J. E. Stead states that in a case where aluminum had been added to ordinary soft open-hearth steel with properly prepared moulds, the castings were very sound indeed. The test bars, which were cast about 8 inches long by ¾ inch square, were perfectly sound, and had a tensile strength of 40,000 pounds per square inch; whereas the same bar, without aluminum, only stood 20,000 pounds, the reason being that in the ordinary steel without aluminum the cavities were very numerous. A few hundredths of one per cent. of aluminum in that casting increased the weight and solidity and reduced the blow-holes by 23 per cent.

There are no such metals as "aluminum steels" in the same sense that there are "nickel steels" and "chromium steels" Aluminum is not a hardener of steel, and none of its alloys with steel in material proportions has so far proved advantageous. It has been proved that the addition of aluminum to steel just before "teeming" causes the metal to lie quiet and give off no appreciable quantity of gases, producing, as previously stated, ingots with much sounder tops.

There are two theories to account for this: one, that the aluminum decomposes these gases and absorbs the oxygen contained in them; the other, that aluminum greatly increases the solubility in the steel of the gases which usually are given off at the moment of setting, thus forming blow-holes and bubbles.

Probably both of these causes operate to produce the desired effect, but the well-known affinity of aluminum for oxygen would point to the former as being the chief action, *i. e.*, in combining with both the carbonic oxide and the dissolved oxide of iron which may be present. Professor Arnold has shown that blow-holes in steel and iron are caused partly by the presence of carbonic oxide gas in the metal, and this gas is decomposed by the aluminum which unites with the oxygen, forming alumina, or oxide of aluminum, setting free the carbon, which appears as uncombined carbon or graphite. It also combines, in some way not yet determined, with the hydrogen and nitrogen present, absorbing the gases or rendering them more soluble in the steel. Aluminum also sets free much of the carbon remaining in the steel, as the following result, obtained by Mr. R. A. Hadfield, will clearly show. Believing that aluminum, like silicon, will cause a precipitation of graphite, he added between 3 and 4 per cent. to ordinary spiegel (with 12 and 25 per cent. manganese). The result was, in both cases, a complete change from the well-known spiegel fracture to that of ordinary close No. 3 gray pig iron.

	C. C.	Gr. C.	Si.	Mn.	Al.	
Spiegel.						
12 per cent. before addition of Al. .	4·80	none.	—	13·65	—	Non-magnetic susceptibility unaltered.
12 per cent. after addition of Al. .	·93	3·45	1·30	11·75	3·19	Fracture changed from usual pronounced "spiegel" appearance to that of No. 3 iron.
25 per cent. before addition of Al. .	4·10	—	—	25·20	—	Do. except the change was not quite so decided.
25 per cent. after addition of Al. .	2·30	1·88	2·16	22·16	1·24	There was considerable loss of aluminum.

Aluminum is the principal deoxidizer known to metallurgists, the next in efficiency being silicon. Their relative values are as follows: 100 parts by weight of oxygen will combine with 114 parts of aluminum, or with 140 parts of silicon, or with 350 parts of manganese. This, however, does not correctly express the value of aluminum as a deoxidizer of iron and steel, as it has so great an affinity for oxygen that it will entirely disappear if there is any oxygen present, and will be found in the steel and iron only after all the oxygen contained therein has been absorbed. This is not the case with either silicon or manganese, as either or both of these are often found in the steel when oxygen is present. There is also an additional inducement for the steel maker to use aluminum, namely, in the cost, for the use of silicon will add from 87 cents to $1.12 to the cost per ton of steel, while sufficient aluminum will not add over 10 cents, and in many cases not more than 6 cents per ton, to the cost of the steel. The saving in bad castings, or unsound ingots, will repay this many times over. One large English steel maker estimates his savings from this source alone at over £2,000 per annum. The special advantage to the steel maker seems to be that aluminum combines the effects of both silicon and manganese.

In most common practice, aluminum is added to steel in the form of the pure metal. In this form, it has the advantage not only of quickly melting and homogeneously alloying, but the manufacturer knows also just how much aluminum he is adding, which is not the case if he purchases alloys of aluminum for adding to the steel.

Some manufacturers, however, prefer to use ferro-aluminum rather than pure aluminum, in their practice.

In this country, the alloy is first placed in the steel ladle, the molten steel from the open-hearth furnace or converter is run in and the alloy is melted and diffused through the steel.

Ferro-aluminum is a trade-name given to 5 or 10 or even 20 per cent. of aluminum alloyed with iron. Either a good grade of cast iron, free from sulphur and phosphorus, or of pure steel low in these elements, is the best material to be used for the purpose of alloying with the aluminum.

Most users of ferro-aluminum make their own ferro-aluminum by adding known weights of pure aluminum to known weights of steel or iron mixture with which they wish to alloy, casting the mixture into convenient moulds.

In the past, ferro-aluminum could be purchased at a cheaper rate per unit of aluminum than the pure aluminum; but this is not the case at present, as pure aluminum can be bought as cheaply as the contained aluminum in any of the alloys.

In cast iron, from 1 to 2 pounds of aluminum per ton is put into the metal as it is being poured from the cupola or melting furnace. To soft gray No. 1 foundry iron, it is doubtful whether the metal does much good; but where difficult castings are to be made, where much loss is occasioned by defective castings, or where the iron will not flow well or give sound and strong castings, the aluminum certainly in many cases allows better work to be done and stronger and sounder castings to be made, having a closer grain, and hence much easier tooled. The tendency of the aluminum is to change combined to graphitic carbon, and it lessens the tendency of the metal to chill. Aluminum in proportions of 2 per cent. and over, materially decreases the shrinkage of cast iron.

The effect of *aluminum in wrought iron* is not very marked in the ordinary puddling process. It seems to add somewhat to the strength of the iron, but this increase is not of sufficient value to induce the general use of aluminum for this purpose. The peculiar property of aluminum in reducing the long range of temperature between that at which wrought iron first

softens and that at which it becomes fluid, is taken advantage of in the well-known Mitis process for making "wrought-iron castings." It is for this that aluminum is most used in wrought iron at present.

The extreme ductility of aluminum makes it one of the readiest metals to work under the rolls. It is best to roll the larger ingots hot—that is, at a low annealing heat.

Aluminum becomes hard and loses its ductility under rolling, and therefore requires frequent annealing during the process. When the plate is soft from recent annealing, it will stand a very considerable reduction in thickness on each pass through the rolls; but as it becomes hard, the draught must be light to avoid cracking.

Aluminum can be rolled so as to be quite stiff. The hardest rolled aluminum has about the temper of hard brass.

Aluminum, either in the pure state or alloyed with a few per cent. of hardening ingredients, can be rolled into any sections into which steel is rolled.

In annealing aluminum, an even heat should be maintained in the muffle, and the metal on being withdrawn should be allowed to cool slowly. The temperature should be such that a piece of iron or steel placed in the muffle in the dark will show a red heat; for annealing the sheet, a much lower temperature will suffice. The best test as to when the aluminum has come to the proper heat is to observe whether the metal will char the end of a pine stick, which should leave a black mark behind it as it is drawn over the plate. The metal should be at this temperature throughout and not only on the surface.

Aluminum, either in the pure state or alloyed with a few per cent. of hardening ingredients, is now sold in the markets by dealers, in the form of ingots, bars, plates, sheets, rod, wire, tubing and in castings. It is fabricated into the forms described above, either by melting or casting, hot or cold-rolling, hammering or drawing, and in a limited way by the "squirting process."

Aluminum under pressure can be "squirted" through dies into almost any shape, if the temperature of from 900° to 1,000° F. be maintained in the metal.

Several devices are used for retaining the heat in the molten aluminum after it is poured into the cylinder in which it is subjected to pressure. In most of these devices the casting cylinder is on trunnions, so that the metal can be poured with the cylinder in a vertical position, after which it is changed to a horizontal position and the piston-plunger inserted and made to act on what was the bottom of the ingot as cast, while the die, giving the desired shape to the metal when drawn, is inserted at the other end. An improvement which has been patented in England, is to have the cylinder in which the metal is cast a composite one, consisting of several cylinders of metal, one within the other, the space between the various metal cylinders being filled with some good non-conducting material which has a high crushing strength; powdered granite is used as a preferable material for the purpose. By means of this device the pressure on the interior metal cylinder is conducted to the outer, thick, cool, and therefore strong cylinders, without the heat of the contained aluminum being conducted away in the same proportion as would take place without the use of the composite casting cylinder. By means of this apparatus, aluminum can be very cheaply and efficiently squirted to almost any desired section.

"Nickel-aluminum" is a trade name for aluminum alloyed with a few per cent. of hardening ingredients, the proportions varying according to the purpose for which the alloy is to be employed. The principal hardening metals so far used with aluminum are copper, nickel, zinc, manganese, tin, chromium, titanium, tungsten and vanadium. Each of these metals has a somewhat different characteristic in the alloy it produces. It has been found practicable, in the best forms of alloys so far used, to combine several of these metals to the best advantage rather than to use them singly.

A considerable difference in the character of the resulting alloy is found according as aluminum used in alloying is comparatively free or not from its two common impurities, silicon and iron. The ordinary commercial metal as now regularly sold upon the markets contains over 99 per cent. pure aluminum, generally running about 99·40 per cent. pure aluminum.

Special attention is given to the fabrication of aluminum

alloys by the Pittsburgh Reduction Company, to avoid oxidation; and to this end, rich alloys are first made, to be afterwards reduced to their proper percentages by re-melting with pure aluminum. These rich alloys are made in the electrical pots or furnaces at the same time that the aluminum is made, in this way more thoroughly combining the metals than can possibly be done by melting them and mixing in crucibles, where their varying melting points render the oxidation from over-heating very liable to occur.

Cast aluminum can be very much improved in rigidity and tensile strength if afterwards subjected to the drop-forging process. For special light-running machinery, drop-forgings of nickel-aluminum casting metal are particularly well adapted.

One of the most promising uses of aluminum at the present time is in the fabrication of *aluminum cooking utensils*.

The lightness, difficulty of corrosion, ease of keeping clean, high thermal conductivity and comparatively high specific heat of the metal, make its use for cooking utensils particularly advantageous.*

*That the Institute may know what the opinions of some of the large manufacturers of aluminum cooking utensils are, I quote from a letter of February 12, 1897, from the Griswold Manufacturing Company, Erie, Pa., one of the largest manufacturers of iron hollow-ware cooking utensils.

"It is about four years since we commenced to cast aluminum into cooking utensils. We began in a small way, and have continued with a constantly increasing demand ever since, until now the outlook for sales is exceedingly promising, and the amount that we reasonably hope to dispose of this year will be very large."

Similarly, I quote from a letter from the firm of Sidney Shepard & Co., Buffalo, N. Y., February 12, 1897, one of the largest manufacturers of stamped metal ware in the country:

"Aluminum cooking utensils are destined, as soon as the extreme hard times which have existed for the past two or three years are over, to meet with a very large sale, for the reason that those who have used them have, in almost every instance, expressed themselves very favorably in reference to them, and our trade has been considerable, notwithstanding the fact that the goods are now unappreciated and higher priced than other ware on the market."

And from the Hill-Whitney Aluminum Company, of Boston, Mass., also large manufacturers of aluminum cooking utensils, under date of February 24, 1897:

"Our cast aluminum tea-kettle business is increasing continuously, as people know the value of such a utensil, and we believe, in the general line of goods, there has been only a beginning."

Aluminum cooking utensils are made both in the form of cast hollow-ware and stamped or spun work.

Many attempts have been made to use soldered joints with aluminum cooking utensils; but in all cases these have proved unsuccessful because of the galvanic action set up between the aluminum and the metal of the solder, occasioning corrosion thereby. I shall refer to this point more fully under the subject of solders for aluminum, to be treated later on in this lecture.

In sheet-metal work of aluminum, relatively better results are obtained with stamped work. Aluminum can be spun as readily as almost any other metal; but it must be borne in mind that the metal is not only light in weight, but relatively to other metals, it is also open in texture. The spinning operation being of such character as to spread apart the particles of the metal, a much more open surface is presented for corrosion. While in many places, spun articles in cooking utensils, as in the tops of tea-pots and similar articles, are in every way all that can be asked of them, where an article can be as well stamped into shape it is always better practice to carry out this method of shaping the utensil.

The cast aluminum tea-kettle is certainly an improvement in household economy, of which every housewife who has used them can speak enthusiastically.

A complaint has been made of aluminum cooking utensils that they turn black by wear. This has sometimes been occasioned where the metal has been subjected to the action of sulphuretted hydrogen, and where the aluminum contained a sufficient amount of copper alloyed with it to form a black sulphide of copper on the surface of the metal; but by far the largest portion of this difficulty can be attributed to the action of ammonium salts, which gradually attack the surface of the aluminum, leaving behind a coating containing silicon, which, although rapidly attacked by concentrated alkali, resists very many solutions of organic matter, as well as moist or dry air. An aluminum surface which has thus been treated has a brown or blackish color. It is really a very serviceable way to treat the metal for a durable finish, to withstand corrosion; but it has occasioned complaint on the part of those who do not

understand the phenomenon as being caused by impurities in the aluminum.

I have investigated several such cases, where only the purest commercial aluminum has been used, and have found that the discoloration referred to was of this surface coating of metallic silicon on the metal.

This action need occasion no anxiety on the part of users of aluminum cooking utensils, as there is no injurious action in the discolored coating, which may be removed by treatment of the aluminum with caustic alkali, doing this by rubbing the metal with a rag dipped in alkali in a way to avoid too serious corrosion of the aluminum. Care, of course, should be taken by one using caustic alkali not to burn or corrode one's hands, as well as the aluminum. With the exception of the looks, this coloration need cause no uneasiness, for there is no real detriment to the healthful use of an aluminum cooking utensil so discolored.

On the other hand, if simply boiling water in a pure aluminum cooking utensil causes this marked black discoloration of the metal, it is a serious indication that the water used is not above reproach, and it usually indicates that the water contains a considerable proportion of free ammonia in solution, which may be occasioned by contaminating sewage.

One of the great advantages of aluminum is that the salts which are occasioned by its corrosion are not in any way poisonous.

Aluminum can easily be kept free from corrosion by the same care that is bestowed on bright work of brass or other metals. In fact, with one-half the work required to keep brass work polished, aluminum can be kept with a nice polish.

Pure aluminum is not by any means as readily corroded as the alloys. The natural impurities of aluminum are silicon and iron, and both tend to render it more easily corrodible than the pure metal. With imperfectly made aluminum, metallic sodium is sometimes alloyed with the metal. Its presence occasions the rapid corrosion of the aluminum.

If the aluminum has been overheated in its molten condition, it is liable to occlude gases, especially nitrogen, which

occasions an open, stoggy, porous metal, which is more easily corroded than pure aluminum.

Aluminum is receiving extended use *in chemical laboratories* for various apparatus, as in water-baths, air-baths, Bunsen burners, hot-water filtering funnels and in condenser tubes.

Prof. T. H. Norton, of the Chemical Laboratory of the University of Cincinnati, has just published in the *Journal of the American Chemical Society* an interesting article on "The Use of Aluminum for Condensers;" the condenser he used being described as follows:

"Outer jacket of glass, inner tube of aluminum, length 122 centimeters, external diameter 1 centimeter, inner diameter 8½ millimeters; weight per meter, 29 grams. At a distance of 15 centimeters from the end, the tube was bent at right angles, permitting connections with a distilling flask, without allowing the condensing vapors to come in contact with any substance but aluminum."

In bending an aluminum tube, Professor Norton recommends filling the tube with molten lead, when the temperature will be attained which allows the tube to be bent as desired.

Professor Norton experimented with organic liquids, alcohol, benzole, nitro-benzole, chloroform, ether, acetone, etc., and states that "very rapid distillations could be carried on with an exceedingly short tube, on account of the high conducting power of the aluminum. The residues obtained showed that there was practically no attack upon the aluminum."

"The deportment of the aluminum condenser toward steam was also carefully investigated; comparative experiments being made with glass and block-tin condenser pipes. The results showed that, so far as purity of the product was concerned, aluminum possessed about the same advantages as glass over tin, in connection with the distillation of water. In lightness and conductivity it exhibited marked superiority over tin."

These careful experiments made by Professor Norton, as well as many other tests made in a similar way by other chemists, have shown that pure aluminum is not corroded seriously by organic solutions or by ordinary water or steam.

My experience with cooking utensils and similar articles, where corrosion has occurred, is to the effect that the cause of the trouble can be traced back either to an excessive amount of hydrochloric acid or chloride salts, or to the presence of caustic alkali solution in contact with the metal.

All aluminum surfaces in utensils, after being wet, should be carefully dried off, if practicable, for with almost all forms of metal one of the most serious forms of attack is by alternate exposure to water, which is allowed to gradually evaporate or dry on the metal; the residues in the water occasioning dirt to settle upon the material and some little corrosion is occasioned on almost every form of metal.

As a Reducing Agent, the element aluminum is already receiving important use. I speak of aluminum as an "element" because it is now universally so considered, which means nothing more than an admission of ignorance on our part as to the possibility to further decompose it. Whether in the light of the knowledge of the next generation our descendants will classify the metal aluminum as an "element," is an open question. As for myself, I am inclined to doubt it.

On April 28, 1891, a patent* was issued to Prof. John W. Langley for the use of aluminum as a reducing agent, in the preparation of alloys of aluminum. He claims therein the "art of alloying aluminum with more electro-negative metals whose oxides or salts are difficult of reduction" by a method "which consists in incorporating such oxide or salt with a molten fluoride bath and then adding aluminum thereto."

At the same time, Professor Langley patented an alloy of aluminum and titanium,† also an alloy of aluminum, titanium and chromium,‡ both made in this manner, and both issued under date of April 28, 1891.

Drs. Greene and Wahl,* in 1891, began a series of investi-

*See U. S. Patent No. 451,404.

†See U. S. Patent No. 451,405.

‡See U. S. Patent No. 451,406.

*Garrison, *Trans. Am. Inst. Mining Eng.*, **21**, 887; Jour. Frank. Inst., **135**, 218.

gations which resulted in the devising of a method of producing metals, free from alloying constituents, by reducing the oxides of these metals with aluminum. The purity of the products thus obtained depends on the purity of the oxides employed. By using an excess of the metallic oxide, it was found that no aluminum remained in the product. In this way, these investigators demonstrated that manganese, chromium and certain other metals, electro-negative to aluminum could be obtained from their oxides in a state of high purity by reduction with aluminum. The process was patented in the United States and foreign countries in 1893,† and has been applied commercially to the manufacture of manganese and chromium. The circumstance that the metals produced by this method, in addition to being practically free from alloying metals, are absolutely free from carbon, should render them of peculiar value in the production of special steels.

Since that time, the noted chemist, Moissan, has called attention of the scientific world to the properties of aluminum as a reducing agent, for the difficultly-reducible metals, using aluminum in fine filings for the purpose. By a process in a general way similar to that suggested by Professor Langley, Moissan has prepared many of the rare metals and has improved on the process of Professor Langley in obtaining these metals in almost a state of purity; that is, with very little alloy of aluminum associated with them. The use of aluminum as a reducing agent is already a considerable one, and bids fair to be a growing business.

According to Moissan,* many alloys can be obtained by taking advantage of the ease with which metallic oxides are reduced by aluminum. The general method is to throw a mixture of aluminum filings and the oxide of the particular metal into melted aluminum. Part of the aluminum burns, and there is so energetic a development of heat that the most refractory oxides are reduced, the metal mingling with the excess of aluminum. In this way, alloys of aluminum with nickel, molybdenum, tungsten, uranium and titanium have been pre-

†U. S. Patent No. 489,303, January 3, 1893.

Comptes Rendus de l'Académie des Sciences, 122, 1302-1303.

pared. An alloy can be obtained containing as much as 75 per cent. of tungsten. The direct preparation of copper-chromium alloy is difficult, but an aluminum-chromium alloy is readily obtained in the manner indicated, and this dissolves in all proportions in fused copper, forming a copper-aluminum-chromium alloy, from which the aluminum is readily eliminated by stirring in cupric oxide, a copper-chromium alloy being left. A similar method can be applied for the introduction of tungsten and titanium into open-hearth steel.

Aluminum seems to be particularly adaptable *for surgical instruments and appliances*, and already considerable sale of aluminum has been made for such apparatus.

Aluminum is used for the *handles of surgical saws, knives* and similar tools and cases in which instruments are kept. Speculum instruments and similar apparatus are being largely made of aluminum.

Aluminum has also been used in tracheal instruments and metal appliances which are placed in contact with living tissues.

The particular advantage of aluminum for these uses is its lightness, and the fact that it is not corroded by carbolic acid and similar antiseptic reagents, which allows the metal to be readily cleaned by antiseptics.*

Aluminum has been used quite largely *for bicycle parts* during the past few years, and the business seems to be a growing one in this country. A bicycle, called the Lu-Mi-Num bicycle, has been placed upon the market and, as a specimen of casting, is really a fine piece of workmanship. The entire

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*Mr. Will McConnell, of Claysville, Washington County, Pa., has an aluminum plate 4 inches long, placed in his jaw, to take the place of a part of the jaw bone. Dr. Louise J. Lisle, of the Presbyterian Hospital, Allegheny City, Pa., performed the operation, and it is proving in every way successful.

A considerable number of persons have aluminum in various parts of their anatomy where it is proving satisfactory; the more common use being being in *aluminum plates* in the mounting of false teeth and *dental work* of similar character. Certain professional dentists are making a specialty of aluminum mountings for false teeth, and there are quite a number of dental surgeons who use the metal more or less extensively in their practice. One important manufacturer in New York uses aluminum largely in the manufacture of *artificial limbs*.

frame of the bicycle is cast in one piece, quite a number of the bars being hollow, in the form of tubes. The frame is cast in metal moulds, with flexible cores, which are removed after the casting is poured.

The secret of the efficient work which is done in these castings, is the process invented by Mr. L. J. Crecelius, St. Louis, Mo., by which the metal is cast into iron moulds which have been heated to a red heat or about the temperature of the molten aluminum, before the aluminum is cast into the same. Large sinking-heads are provided and the metal is cooled from the bottom of the casting upwards, by blasts of air upon the outside of the metal mould, the metal in the "riser" being kept molten the longest and taking the shrinkage from the mould. As soon as the casting is cooled sufficiently, the mould, which is made in halves, is opened up and a perfect casting taken out of the mould.

Many special alloys have been used in the making of bicycle frames, handle-bars, etc. In Europe, there is at present a good deal of talk about an alloy called "Alcolite," which has been produced as the result of the experiments of Mr. Wm. Pearson, Birmingham, England. Another alloy which has received widespread advertisement in Europe is "Romanite."

These various alloys are simply pure aluminum hardened with a few per cent. (ordinarily less than 10 per cent.) of nickel, copper, titanium, manganese, zinc, tin and similar metals. The composition of these alloys can in all cases readily be told by chemical analyses. All of these alloys stand in relation to the metal aluminum as the various grades of steel are related to iron. The experience of the Pittsburgh Reduction Company with the alloying metals as hardeners is to the effect that copper and nickel, while hardeners to a certain extent, do not render the metal as hard as do many other alloying metals. They are advantagous to be used as carriers, permitting the proportion of the hardening material to be increased, and to give toughness and ductility to the product; but where extreme hardness is desired, zinc, manganese and titanium give much more efficient results, although all of these, unfortunately, render the alloy more brittle than does nickel or copper alone.

In Great Britain, the latest forms of aluminum bicycles do not have the frames made in one piece, but aluminum tubes are used, which are drawn on mandrels from hollow tube ingots and have the advantage of the worked metal over castings, in both strength and ductility.

These tubes are brazed by a secret process, and, by the use of the X-ray apparatus, are shown to be perfectly welded joints.

The Pittsburgh Reduction Company has also a considerable demand for aluminum to be used for cast aluminum brake-shoes for bicycles, as well as for aluminum sheet for rims. Aluminum mud- and chain-guards, both in cast and stamped metal work, are being made.

Aluminum has been used successfully for *lithographic work*, the light plates being used in place of the heavy and expensive lithographic stone which has been used in the past.

The Ellery-Howard firm, of New York, claims to have a patent on the surface printing from aluminum plates, with patents relating to certain rotary presses for the use of the aluminum plates.

A German firm also claims to have patents for surface-printing with aluminum plates. This firm uses in the work a flat-bed press instead of a rotary press.

The advantages claimed for the rotary press are that some 25,000 impressions per day can be obtained with a rotary press, where only 8,000 impressions can be obtained with a flat press. The number of impressions which can be taken with a rotary press depends principally upon the speed with which the printed sheets can be removed from the press. There is not room for more than three men to work around the mouth of the press, and 25,000 is about all they can handle, if the sheets are large.

Aluminum plates for lithographic purposes are grained as follows:

They are either sand-blasted, with a sand which is not too fine, or they are grained by placing them in a horizontal position in a sort of cradle with marbles about an inch in diameter, which come for the purpose of graining zinc plates, etc. These plates are rocked in this cradle with the marbles, sand

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and water, in the usual way. After the plates have been either sand-blasted or grained, their surfaces are treated in order to remove any foreign matter, by first cleaning them with benzine, then dipping the plate in caustic potash, then into a solution of nitric acid, and washing in hot water. After this is done, the plate can be worked on with pen and ink, and will take impressions from a specially prepared transfer paper, which is used by lithographers.

In another lithographic process different from that just described, the aluminum plate is covered with a very thin coating of copper. The transfer is then put on with a prepared ink, which the acid does not attack. Then the plate is treated with an acid which attacks the copper and does not attack the aluminum. The copper is eaten away down to the aluminum and leaves a printing surface which really stands in relief like an electrotype. This process seems to have a promising future.

For letters and signs, aluminum has become quite extensively used, not only in the form of fine powder or bronze, but also in heavy cast aluminum letters, which can readily be attached to glass as well as to wood. There are several companies in the United States which make a specialty of this business, and I take pleasure in showing some specimens of this class of work.

Aluminum has not yet been used, but has been proposed in the fabrication of passenger coaches, for use both in the roof and sides of the car, as well as in the fittings around windows, etc. There is just now under consideration by one of the leading railroads of the country a proposition to build some cars along the line just outlined; and it is my opinion that in the course of a few years there will be a considerable use of aluminum in railroad passenger cars and their fittings.

A type of passenger coaches finished with copper on the outside in place of the usual paint and varnish, is being put into service on the New York, New Haven and Hartford Railroad. The advantage claimed is that the cars are more readily kept in condition of cleanliness and brightness, and when it is necessary to send a car to the shops for exterior overhauling, it is

ready for the service again in half the time required to paint and varnish it. All the wood paneling and sheathing is made in precisely the same manner as at present, except a shade thinner, and a light coating of copper is formed around the wood, fitting closely into all curves and corners. Each piece of sheathing and its strip of copper are passed through the machine simultaneously and come out ready for use with the copper wrapped tightly around the wood. After the sheathing and other members are covered or plated with copper they are applied to the body of the car in such a manner that the exposed surfaces are not punctured by nails or other fastenings, so that when completed the casual observer would not notice but that the car was finished with paint and varnish. All joints are absolutely water-tight.

Only one car has thus far been finished in this way, and the copper on this car was oxidized, giving it a dark, glossy finish very similar to that of the ordinary Pullman coach. The next car will be put on the road without this, as the copper will oxidize in the atmosphere, attaining in a few days a deep rich bronze tint. No paint or varnish is used on the outside of the car, excepting on the roof, platform, hoods and window sash. The numbers and letters are made of cast aluminum and are attached by screws. It is also believed that the new copper-coated cars will improve in appearance with wear rather than be dulled by it, and the cost of cleaning and keeping the exterior in condition will be very materially reduced. If the car be injured, unless the copper is punctured or torn, it can be taken off, re-rolled and put on again. The weight of the car is not increased by this method of finishing; in fact, in the car just put into service the weight was lessened, owing to the wooden members having been thinned sufficiently to compensate for the difference in the weight of paint and varnish and that of copper.

It is evident that aluminum sheet can be advantageously used in the same way. The metal can be given a dull finish in many shades equally as well as can copper sheet.

Aluminum is now being used in metal appliances in street railway cars. For the handle-bars of these cars, there is a par-

ticular advantage in the use of aluminum over brass. In the summer time, when the conductors have to handle with perspiring hands the brass handles, the corrosion of the brass in many cases occasions sore eyes and affections of the mucus membranes, occasioned by the hands becoming impregnated with these copper salts.

Aluminum bronze-powders, as they are called in the trade, have almost entirely replaced silver bronze-powders. Aluminum bronze-powder is simply finely-powdered aluminum metal. In the best grades, it is pure aluminum thus prepared, but in the cheaper varieties, now largely sold in the markets, the aluminum powder is adulterated often with as much as 50 per cent. of tin powder. As pure aluminum corrodes less rapidly and is entirely unacted upon by sulphuretted hydrogen, it is more durable than silver powder, and the article adulterated with tin, and is therefore superior to them.

Aluminum bronze-powder is used as a paint on signs and bronze-printing work, as well as very largely for interior decorations.

Because of the extreme malleability and ductility of aluminum, it is preceded in the relative order of malleability of the metals by gold only, and in the order of ductility by gold, silver, platinum, iron, soft steel and copper. Both malleability and ductility are impaired by the presence of the two common impurities, silicon and iron. Aluminum of over 99 per cent. purity is rolled into sheets of only five to seven ten-thousandths of an inch in thickness, and such sheets are hammered into leaf nearly as thin as gold leaf can be beaten.

Aluminum leaf is largely used for decorative work, and on account of its relative cheapness and non-tarnishing qualities, it has almost entirely superseded the use of silver leaf. Aluminum leaf is ground up into powder and used in large quantities for the pigment of a decorative paint, called by the trade "aluminum bronze paint."

Painting with aluminum bronze is done in two ways:

(1) By thoroughly mixing a certain amount of bronze-powder with the varnish and applying with a brush.

(2) By varnishing the surfaces first and then, with a small

brush of raw cotton dipped in the bronze-powder and used as a powder puff, applying the powder.

By this latter way, all of the aluminum bronze-powder is located on the surface, and a brighter painted surface is obtained.

Aluminum has been used to harden rubber, in the vulcanizing process; also to give it a peculiar golden-yellow color.

Cast aluminum bath tubs, sinks and similar plumbers' supplies are now being made by the Western Brass Manufacturing Company, of St. Louis. I have in my own home a cast aluminum bath-tub and cast aluminum sink, both of which are giving excellent satisfaction. Both, however, require care in being washed clean from the soapy residue after use; but with such reasonable care as is ordinarily taken in keeping iron free from rust, these articles are giving excellent satisfaction.

Aluminum has been used quite extensively for *oil cups* and other parts of light-running machinery, where reciprocal motions are made and the momentum of the moving parts occasions considerable strain upon the material. In such cases, the lighter weight of aluminum has been of special advantage.

Aluminum, especially in forms where it is alloyed with a few per cent. of hardening ingredients, is now being used very largely *in castings of all descriptions*, where lightness, non-corrodibility, or a silver color is desired. The alloys most used in general castings have a tensile strength of about 20,000 pounds to the square inch, and are about one-third the weight of brass.

The same general method is followed as in making brass castings. Either iron or sand moulds can be used. The metal should be poured as cold as possible, in order to insure sound castings, free from blow-holes (caused by the very great absorption of gas by overheated molten aluminum), or cracks and depressions due to shrinkage. It is also desirable in most cases to use large gates and risers, as a further safeguard against these defects. The gate should be put in such a place on the casting that the metal will not "draw away" where the gate joins the piece. Particular care should be used for this reason in making "gated patterns."

The practice of some moulders is to immerse small quanti-

ties of nitre in molten aluminum to purify it, the oxidizing effect of this salt undoubtedly acting somewhat beneficially if care is taken to see that all of the potash salts are allowed to come to the surface and are skimmed off, to prevent contamination of the metal.

The method of adding nitre in foundry practice is as follows: After the metal is removed from the fire, and before pouring, slightly dampen a sheet of writing-paper with water. Put in this paper one tablespoonful of nitrate of potash to about 100 pounds of metal. After the nitrate of potash has been wrapped in this paper, it should be placed on the top of the molten metal, and instantly, with an iron ladle or stick, it should be pushed to the bottom of the pot. By the time it reaches the bottom the paper burns, and the nitre comes up through the metal, combining with the oxide as it comes to the surface. It is then skimmed off.

Charcoal is the best fuel to use in melting aluminum, and should be used in all cases where especially good castings are desired. Both coke fires and natural gas are successfully used in melting aluminum. Care should always be taken, not only to not overheat the metal but also to prevent the occlusion of gases in aluminum. Both nitrogen and hydrocarbon gases are especially liable to be absorbed by molten aluminum. Care should also be taken to have the flasks well vented.

Aluminum is melted in ordinary plumbago crucibles, such as are used for melting brass. If the metal be not overheated, it will absorb no appreciable amount of silicon from the crucible. Aluminum remelted twenty times in such a crucible showed only an addition of one-tenth of 1 per cent. of silicon.

Aluminum does not unite with or absorb carbon in any considerable quantity when heated in contact with it, unless the metal be heated much above its melting point.

The melting point of aluminum is 1,157° F., or 625° C. At about 1,000° F. the metal becomes granular and can easily be broken. [The melting point of copper is 1,929° F.; that of cast iron, 2,372° F.]

No flux is needed to cover aluminum, for it is non-volatile at any temperature that can be attained with any ordinary coke

fire without blast. A very thin film of oxide forms on the surface of the molten metal, which, while not enough to injure either ingots or castings, protects the metal from further oxidation.

SHRINKAGE OF CASTINGS OF METALS.

	Inch to the Foot.
Pure aluminum ($\frac{1}{4}$ inch)	·2031
"Nickel Aluminum Casting Alloy" ($\frac{1}{8}$ inch)	·1875
"Special Casting Alloy" of the Pittsburgh Reduction Company, ($\frac{1}{4}$ inch)	·1718
Iron, small cylinders	·0625
" pipes	·125
" girders, beams, etc.	·100
" large cylinders, contraction of diameter at top	·625
" " " " " " " bottom	·083
" " " " in length	·094
Thin brass castings	·167
Thick brass castings	·150
Zinc	·3125
Lead	·3125
Copper	·1875
Bismuth	·1563

The use of *aluminum in the galvanizing bath* has become so universal that at the present time it is considered a necessity in order to produce the best and most economical work. It is added in the form of aluminized zinc, which is made according to a process devised and patented by Mr. Jos. Richards,* of Philadelphia, and a member of this Institute. This aluminized zinc is used in such proportions that the total amount of aluminum in the bath will be about 1 pound of aluminum per ton of bath, or in using a 5 per cent. aluminized zinc, 20 pounds of aluminized zinc per ton of bath should be used. These proportions, however, are varied according to the grade of zinc which is being used, and also upon the class of material to be galvanized. In some cases more, and in some cases less than the quantities given above will be found most advantageous.

When aluminized zinc is used, it has been found unnecessary to use sal-ammoniac, for clearing the bath of oxide, as the aluminum accomplishes the same purpose; and if the two are used together, they seem to counteract the effects of each

*See U. S. Patent No. 456,204. July 21, 1891.

other. Aluminized zinc should be added to the galvanizing bath gradually, and not all at one time; and as the bath is consumed, fresh aluminized zinc is added in the proportion of about 1 pound at a time, for a 5-ton bath. This is when a 5 per cent. aluminized zinc is used.

The first action of aluminum in galvanizing baths is to make the bath more liquid, which is one of the objects in adding the aluminum; a greater amount of aluminum seems to combine with the impurities in the zinc and come to the surface in the form of a scum, which makes galvanizing difficult. If, therefore, too much aluminum goes into the bath, the bath should be well stirred and allowed to stand for a while until the aluminum combines with these impurities and comes to the surface as a scum. The scum should then be removed, some sal-ammoniac should be added to counteract the effects of the aluminum and the proportion of the aluminized zinc added should be reduced. In starting with a new bath, it is especially important that these suggestions should be followed.

Aluminized zinc is made by first melting the aluminum in a plumbago crucible and adding thereto zinc in proportions necessary to form the alloy of aluminized zinc required—ordinarily, 5 to 10 per cent. of aluminum with the zinc is used in common practice.

Aluminum has been used quite largely in *improving the quality of brass castings.* Brass is a mixture of copper and zinc, as distinguished from the bronzes, which are alloys of copper and tin. The proportions commonly used in making brass are 66 parts copper, 34 parts zinc. It is customary in the manufacture of ordinary commercial brass to introduce from 2 to 5 per cent. of tin for the purpose of giving added strength and density.

The terms "high brass" and "low brass" are used in he trade, but apply only to rolled material. High brass is composed of 2 parts copper and 1 part zinc, being a light color. Low brass is composed of 75 to 88 per cent. copper and 25 to 12 per cent. zinc, and in color is considerably darker than high brass. In ordinary commercial practice, cheap brass is a very heterogeneous material, much of it containing lead and some

iron alloyed with it, either accidentally or for the purpose of giving an additional weight of cheap metals.

Aluminum has been added to brass with advantage in giving a stronger alloy. It has been used in all proportions from one-tenth of 1 per cent. to 10 per cent.; and the best results have been obtained by introducing the aluminum in the form of aluminized zinc. This is added in the same manner as zinc is ordinarily introduced into the copper, and in such proportions as will give the requisite amount of aluminum in the brass mixture.

The effect of aluminum in brass, added in this manner, in small quantities of less than 1 per cent., is mainly to make the brass flow freely and present a smooth surface, free from blow-holes. When used in these quantities, from one-half to one-third more of small patterns can be used on a gate than can be used without the presence of the aluminum, for this amount of aluminum gives the brass such additional fluidity as to cause it to run more freely in the moulds and to a greater distance; consequently more patterns can be used on a gate. In quantities of over about 1 per cent., the effect of the aluminum commences to be very perceptible, from the fact that it imparts to the brass additional strength, and this strength is increased directly as the percentage of aluminum is increased, up to about 10 per cent. One per cent. of aluminum in brass is very extensively used for electrical purposes, as it gives a brass casting free from pin-holes and of greater strength than can be secured otherwise, from the same grade of brass. It follows, therefore, that by the use of a small percentage of aluminum in brass, a cheaper grade of brass can be used to do the same work than would otherwise be possible.

In all cases, if maximum results are desired, care must be taken that only pure metals are used. In connection herewith, it should be clearly understood that much of the copper and zinc commonly used contains considerable amounts of impurities, and the nature of some of these impurities is such as to absolutely prevent the production of good alloys with aluminum. In all cases, we would advise intending purchasers to insist on being furnished with an analysis of the metal supplied.

and for aluminum alloys, to exclude all containing more than one-fourth of 1 per cent. of iron, arsenic, or antimony, or more than two-hundredths of 1 per cent. of bismuth. Alloys should be poured at a low heat as soon as fluid.

It should be noted that the presence of aluminum in these alloys lowers the point at which they become fluid, and that they are fluid at lower temperatures than either gun-metal or ordinary brass mixtures; therefore the average brass founder is very liable to overheat them, and great care must be taken to prevent this.

To illustrate the great differences which occur in metals found in the open market, the following are given as analyses of metals, some of which are good and others worthless for making good alloys:

ANALYSES OF METALS.

	Best Copper.	Tough Copper.	Bad Copper.	Good Tin.	Bad Tin.	Good Zinc.	Poor Zinc.
Copper	99·861 99·84	99·67	98·04 98·02	—	— —	trace	—
Tin	·0	—	— —	98·60	95·55 95·80	·020	—
Zinc	·0 trace	—	— —	—	— —	99·656	98·76
Silver	·053 ·061	—	— —	—	— —	—	—
Lead	·017 ·0	—	— —	·034	·567 3·04	·158	1·09
Bismuth	·0 ·0	·015	— —	—	— —	·0	·03
Iron	·030 ·0	·018	— —	·09	·812 ·714	·093	—
Nickel	·039 ·05	—	— —	—	— —	—	
Arsenic	— —	·177	1·27 1·40	—	— —	trace	trace
Antimony	— —	·0	— —	trace	2·58 ·121	·0	—
Sulphur	— trace	—	— —	—	— —	·073	—
Oxygen	— 0·26	—	— —	—	— —	—	—

The use of aluminum in cheap ordinary brass mixtures has sometimes occasioned the complaint that the surface of the brass castings is made black by the addition of the aluminum. This is due to the sweating out of the lead from the brass mixture, which the impure brass has contained.

It is not advisable to use aluminum in brass which is to be dipped in acid, as the aluminum, even in small quantities, makes the metal withstand the action of the acid so com-

pletely that the dipping is not successful. For this reason brass, which is subject to corrosion, is found to withstand this corrosion much better if it contains a proportion of aluminum, up to, say, 10 per cent.

The main objection to the considerable addition of aluminum to brass is the increased shrinkage of the alloy occasioned by the use of the aluminum. This has to be provided for by pouring the metal not too hot and using large gates and risers.

Aluminum-brass has an elastic limit of about 30,000 pounds per square inch and an ultimate strength of 40,000 to 50,000 pounds, with an elongation of 3 per cent. to 10 per cent. in 8 inches.

The use of *aluminum-bronze* is gradually increasing, for purposes where a strong and dense metal is required.

On account of the difficulty of making sound castings, and especially in rolling ingot-slabs capable of turning out sound sheets, the business has grown much more slowly than the bright prospects claimed for the use of aluminum-bronze eight or ten years ago would seem to indicate.

It is necessary now in the preparation of rolling slabs of aluminum-bronze that each ingot shall be planed off on the top until sound metal is obtained below the blow-holes, which always exist on the surface of the castings. This planing of the metal is expensive, due to the hard, dense character of the metal.

In the manufacture of aluminum-bronze, the best results will be derived by following closely the following method of manufacture:

Both the copper and the aluminum should be carefully selected, and none but the purest "Calumet and Hecla Mine" or "Lake" copper should be used and the aluminum should be guaranteed to be at least 99 per cent. pure.

The copper should be placed in a plumbago crucible, and melted over a charcoal or coke fire; these being the best fuels to use. Next to charcoal or coke as a fuel for melting comes oil, and then natural gas or producer-gas. It is impossible to make satisfactory aluminum-bronze over an ordinary coal fire, for the reason that the copper will absorb the gases from the

coal. The copper should be covered with charcoal to prevent as far as possible oxidation and the absorption of gases, as there is always the liability of a small amount of gases being present, even in using the fuels previously mentioned.

After the copper has been melted, and the time has arrived to introduce the aluminum, the crucible should be grasped with tongs in order to remove it from the fire instantly, and the percentage of aluminum which it is desired to add, dropped into the pot through the charcoal.

In large pots of bronze, the pot may be removed from the fire before adding the aluminum. As soon as the aluminum goes into the pot, the first action, to a certain extent, will be a cooling one, caused by the actual temperature of the aluminum; but as aluminum and copper form natural alloys (*i. e.*, combinations in atomic proportions), the aluminum, as soon as it is heated to its melting temperature, enters into combination with the copper, by which a large quantity of latent heat is set free (or made sensible) by the chemical union of the two metals, and consequently the temperature of the mass is raised. If the mixture be watched, one can tell as soon as union takes place, for the reason that the copper will become more liquid, and also turn a little brighter in color.

This occurs in an instant after the aluminum is introduced; then, if the crucible has remained on the fire, it should instantly be removed, the charcoal skimmed from the surface, and the metal, which is now aluminum-bronze, poured into moulds of any convenient size, keeping the liquid metal in agitation by constant stirring until it is poured, in order to insure that the aluminum is as well disseminated through the alloy as possible.

If these points are strictly adhered to, good castings can be produced.

After this aluminum-bronze has become cold, it should be re-melted and poured into moulds as desired, for the purpose of manufacturing finished castings. Aluminum-bronze is found to improve with each successive re-melting and casting, until this has been accomplished three or four times, for the reason that it seems to give the aluminum a better chance to become

more freely disseminated, and form a more uniform alloy with the copper.

The amount of aluminum in aluminum-bronze varies from a few per cent. up to 10 or 11 per cent., depending on the purpose for which the metal is intended. The strongest mixture contains between 10 per cent. and 11 per cent. of aluminum. Beyond this point, the bronze is hard to work, and becomes brittle.

Aluminum-bronze can readily be soldered. In soldering this alloy no such difficulty is encountered as is found in soldering pure aluminum. The best method of soldering aluminum-bronze is to use pure block tin with a flux made from zinc filings and muriatic acid. It is well to "tin" the two surfaces before putting them together.

[*To be concluded.*]

PISTON PACKING RINGS OF MODERN STEAM ENGINES.

By Otto C. Reymann,
With Westinghouse Electric and Manufacturing Company, Pittsburgh.

I. Only a few years have passed by since, with adoption of the multiple expansion system, the capacities of steam engines have grown considerably. Units of more than 1,500 horse-power and even 2,000 horse-power are found quite frequently nowadays. Not only the rapidly increasing use of electricity demanded larger and more economical steam engines for the equipment of power and lighting stations, but also the wants of modern marine engineering grew. The advantages of the multiple expansion steam engines having been demonstrated once, manufacturers very soon centralized their power plants, and put in large units, thus doing away with a great number of small steam engines, generally distributed over the factory.

The principal feature of the multiple expansion system lies in the use of high-pressure steam, and consequently in the pos-

sibility of utilizing the benefits of a greater expansion. Taking in consideration that the capacity of an engine, besides other factors, is directly proportionate to the area of the piston and the mean effective steam pressure, it is evident that, retaining the same piston speed, either or both factors had to be increased in order to obtain an engine of larger output. Using steam of high pressure and pistons of larger diameter a greater strain is exerted upon the piston itself. Necessarily, this demands a heavier construction of the piston block and its packing rings.

Besides this, the working conditions are rendered much worse. Instead of slow-speed engines, for instance, the equipment of electric plants requires high-speed steam engines suitable for direct connection to dynamos.

Units of 1,500 to 2,000 horse-power running at 75 to 90 revolutions per minute are to-day's standard for work of this kind. The desire of cheapening the engines by cutting down the over-all dimensions offered an inducement for adopting higher piston speeds—little desirable, considering the piston weight and its increased oscillating mass. Especially of horizontal engines with the weight of the piston resting on the lower side of the cylinder is this true and constituted a serious objection to this type of engines. Not only that the piston block is more strained by a greater piston speed, but the packing rings are subjected to a greater wear also, since friction of surfaces depends mainly upon their smooth condition, the pressure exerted upon the surfaces and the rate at which they slide along each other. From this, it will easily be recognized that the pistons of modern high-speed steam engines have to work under unfavorable conditions. And yet the proper function of the piston and especially of the packing rings is of the utmost importance.

Let us investigate what the piston of a steam engine has to perform. Certainly it is more than offering the steam a surface to act upon and to move it back and forth, thus driving the crank shaft. Economy demands that this be done with as little waste of steam as possible, *i. e.*, the piston must be steam-tight, preventing the steam from escaping to the exhaust side. This

task is a rather difficult one and is not always accomplished satisfactorily. Innumerable contrivances have been adopted, having this end in view. Modern practice in steam engineering, however, has settled on metal packing. Taking a theoretical standpoint, packing is superfluous; for a piston turned mechanically true and fitted to a perfectly cylindrical hole will be tight and does not require any packing. But, even should original workmanship be sufficiently good as to dispense with packing, subsequent wear will demand its use. Furthermore, the influence of not evenly distributed forces acting upon the piston results in uneven wear of the rubbing surfaces, not to speak of the fact that piston and cylinder are expanded unequally by the steam heat.

The packing now generally used for steam engines consists of metal rings carried in suitable grooves, which are turned in the circumference of the piston block. Consequently, the rings slide along the cylinder walls at the same speed as the piston; to assure a steam-tight fit, the rings must be pressed outward against the cylinder bore, thus producing friction.

Leaving quite out of consideration how much this friction amounts to, it is obvious that the power of the steam engine used up in overcoming this resistance is altogether lost. Prof. R. H. Thurston demonstrated that the work wasted in piston friction is the largest item of the total internal friction losses of a steam engine, next to the friction of the main bearings. Badly-fitting piston rings in many cases are the cause of an abnormal steam consumption, and here the absolute necessity of well-working piston rings expresses itself in many a pound of steam passing through the cylinder into the exhaust without doing its work.

The work lost by piston friction as well as by escaping steam due to leakage around the packing rings must bear on the efficiency of the whole machine, and it follows that the piston must be kept steam-tight with as little pressure exerted upon and by the packing rings as possible. If the pressure of the packing rings upon the cylinder walls could be varied, the most favorable working conditions combined with the highest efficiency of the steam engine would be attained.

The problem involved presents itself in the simple question: How are packing rings for steam pistons to be designed in order to exert a certain amount of pressure upon the cylinder walls?

Before answering this question, it will be necessary to dwell for a moment upon the different methods of securing a steam-tight piston employed in modern steam engineering.

II. As mentioned in the first chapter, modern practice has discarded all hemp packings and decided in favor of an elastic metal packing ring for use in steam cylinders. With packing rings a steam-tight joint can be maintained in three different ways, viz.: the packing ring is pressed outward toward the cylinder walls:

(1) By its own elasticity.

(2) By the pressure of the steam which finds access behind the packing rings.

(3) By especially provided springs.

Of these three methods the second is employed always. Necessary allowances in width of the grooves, gradually increased by unavoidable wear, enable the steam to pass through the narrow passage between the side walls of the groove and the ring behind it. The use of special springs, called packing springs, is a modification of the method named in the first place. Springs are necessary if the initial elasticity of the ring is not sufficient to guarantee a steam-tight joint. Either the ring may have such a form as to give no spring action at all, or the material employed may have little elasticity itself. Where packing rings are made of gun metal, for instance, a steel ring or springs may be placed inside the ring, in order to exert a uniform pressure all around it. Steel or cast iron have by far a greater elasticity, and especially the cast-iron rings are found to be superior to all others for durability and satisfactory wear.

In the case where packing springs are used the piston ring is turned of the same size or a certain amount larger in diameter than the cylinder bore. They are then divided at one point to allow the packing springs placed inside to expand them.

If the steam-tight joint depends only upon the elasticity

of the packing rings, they are made in two different ways. If wrought iron or steel is chosen, the rings are drawn of a suitable cross-section to fit the grooves in the piston block and then are bent to the proper curvature by rollers.

Where cast rings are to be employed, they are not cast individually, but cut off a cylinder of the proper thickness and of sufficient length to yield the required number of rings. This cylinder is turned all over, either inside and outside, concentric or in such way as to give rings of varying thickness. Their outside diameter is turned a certain amount larger than the bore of the steam cylinder. Consequently, the packing ring would be too large and a portion of its circumference must be cut out, so as to allow the compressed ring to be introduced into the steam cylinder.

It is obvious that the reaction of the force which is necessary to compress a packing ring in order to introduce the piston into its cylinder, afterward expands the ring and presses it outward against the cylinder walls, aided by such steam pressure as comes behind it. From this follows that the pressure which can be exerted by a packing ring depends mainly upon its material, its outside diameter and cross-section, the form of its curvature being only essential for an even distribution of the pressure all around the circumference. The question arises then: How much pressure has a piston packing ring to exert in order to maintain a steam-tight piston?

Although this question cannot be answered thoroughly by calculation, since the working condition of a piston is the most essential and ever-varying factor, its importance was recognized early; and as a result the only way of solving this problem, viz.: by experiment, was tried successfully. As far as the writer's researches went, however, an application of the data thus gained upon theoretical calculations of the strength of piston packing rings could be found only for the Ramsbottom rings.

In the following chapters the writer will derive additional formulæ for those ring types generally used beside the Ramsbottom rings.

III. In the experiments carried out with the assistance

of the writer,* rings taken from pistons for locomotive engines as used by the railroads in Germany were dealt with. These pistons carried originally bronze packing rings, which were faced with babbitt metal. As the elasticity of these rings was very small, they had to be expanded by springs placed inside. Owing to the heavy duty and severe shocks of the engines, in less than six weeks the babbitt metal was worn off, and the piston had to be taken out of the cylinder in order to adjust the packing springs or replace the rings altogether. This rather annoying and expensive work led to a trial of cast-iron rings, of sufficient elasticity as to dispense with special springs. At the same time a series of experiments was undertaken, in order to determine the proper shape and cross-section of these rings. Cast-iron rings, especially made for testing purposes, and similar to those which had been in use for some time, were tested as well as rings well worn out. Originally, these rings had been uniformly ¼ inch thick, the smallest ring being ¾ inch wide, and the larger sizes about 1¼ inches. Their outside diameter varied from 14 inches to 18 inches. The length of the cut in the circumference averaged about one-tenth of the ring diameter.

Two different methods were adopted in measuring the pressure a compressed packing ring exerts radially. *Fig. 1* shows the manner in which the rings were suspended during the first series of tests. By four cat-gut strings the ring was held in a horizontal position, the upper ends of the strings being firmly fastened at one point, while the other ends carried a weight P. From the figure it will be seen that the total pressure exerted upon the ring at points X is equal the sum of the horizontal components of P; namely,

$$\Sigma W_1 = 4\left(\frac{P}{2} \tan \alpha\right)$$

and if angle $\alpha = 45°$

$$\Sigma W_1 = 2P$$

The required length of each string

*The experiments were made, 1878, by Mr. Charles Reymann, then Superintendent of Motive Power of the Berlin-Hamburg Railroad in Germany.

$$l = 2\,r\,\sqrt{2} + h$$

By this method the ring pressure is measured directly, whereas in another series of tests an indirect method was employed. As illustrated in *Fig. 2*, the ring was placed in a loop formed by a piece of wire. The one end of the wire being fixed, the other was loaded until the ring was compressed to a diameter ($=2\,r$) equal to the bore of the steam cylinder.

Let us call W the weight which is required to close the ring to the required diameter $= 2\,r$, and let us designate with M the resisting moment of the cross-section at C opposite the cut, then

$$W\left(2\,r - \frac{t}{2}\right) = M$$

The thickness of the ring is generally small compared with

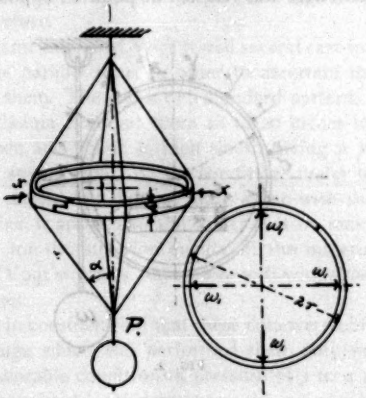


FIG. 1.

its diameter, and we may neglect $\frac{t}{2}$ against $2\,r$ without material error for practical use, putting

$$W = \frac{M}{2\,r}$$

If p, the pressure per square inch which results from the

elasticity of the packing ring and acts radially outward, is constant for the whole circumference, the expanding force of the upper half, $A\ B\ C$, will be $= 2\ r\ h\ p$, and the bending moment at cross-section C

$$M = 2\ r\ h\ p\ .\ r$$

Since the load W is constant for the whole ring, we can substitute the value of M in the equation for W and write thus:

$$W = \frac{2\ r\ h\ p\ r}{2\ r} = h\ p\ r, \text{ or } p = \frac{W}{h\ r}$$

The depth h and the radius r being known and with W obtained by experiment, the unit pressure p can be calculated from the last formula.

It was found thus that p varied from 2¾ pounds up to 4½ pounds, in some cases, however, falling as low as 2¼ pounds. The greatest stress was reached at point C, opposite the cut,

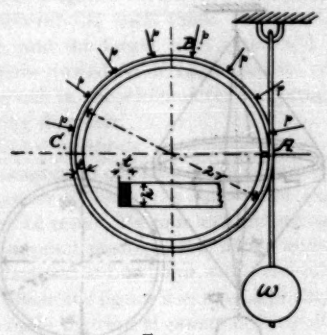


FIG. 2.

averaging 12,500 to 13,500 pounds per square inch. These rings only seldom broke, in spite of the heavy strain on them, a fact which speaks well for the quality of the cast iron used.

Upon an inquiry made by the writer concerning the strength of the cast iron used for packing rings by the Pennsylvania Railroad, Mr. Vogt, Mechanical Engineer of the Pennsylvania Railroad in Altoona, Pa., had made a number of trans-

verse and tensile tests with different mixtures.* Cast-iron pieces originally 1⅜ inches square by 15 inches long, which were planed off as nearly as possible to 1 inch square, were used for the transverse tests. The tensile test pieces were turned down from 1⅜ inches round to 1 inch in diameter in an 8-inch section. The following table gives averages obtained from these tests:

Kind of Mixture.	Ultimate Tensile Strength.	Greatest Bending Stress.	Coefficient of Elasticity.
Machine Iron	18,000 lbs. per sq. inch	42,000 lbs. per sq. inch	12,800,000 lbs. per sq. inch.
Eccentric Iron	24,850 " " "	59,000 " " "	13,800,000 lbs. per sq. inch.

As will be noticed, the bending stress appears to be in both cases 2 1-3 times the stress for pure tension, the elastic limit of the eccentric iron being about 30 per cent. higher than that of the first mixture.

At the same time, Mr. Vogt tested several cast-iron packing rings of the parallel type, in order to ascertain the pressure exerted by them. The rings, of a standard pattern, as used by the Pennsylvania Railroad, were 18 to 20 inches in diameter, ½ inch wide and about ¾ inch thick, giving a p of 6 to 7 pounds per square inch. As the conditions under which these tests were carried out did not quite agree with those met in actual service, it appears to the writer that by making proper allowances for the superior quality of the material in these rings, Mr. Vogt's results harmonize well with those obtained by the writer.

Taking in consideration that these data were obtained from packing rings which had performed their duty satisfactorily under unfavorable conditions a pressure of 3 to 4 pounds per square inch exerted by the ring upon the cylinder bore can be considered sufficient to guarantee a steam-tight piston.

IV. *The Parallel or Ramsbottom Ring.*—The parallel ring is the simplest type of piston packing rings, having a uniform cross-section all the way through. It is either drawn of a suit-

*The writer avails himself of this opportunity to thank Mr. Vogt for his valuable information.

able section and bent in rollers to the proper curvature, if made of wrought steel, or it is cut off a cast cylinder of sufficient length, properly finished. At one point the ring is divided by cutting out a piece of its circumference. The length of this cut depends upon the difference between the outside diameter of the free ring and the bore of the steam cylinder, which the compressed ring has to fit. The two ends are generally shaped in such a way as to prevent the steam from leaking through the cut after the ring has been sprung into its groove in the piston block; a lapped joint is shown in the accompanying sketch, *Fig. 3*. As no special springs are used for pressing the ring outward against the cylinder bore, the elasticity of the material alone is depended upon in securing a steam-tight joint.

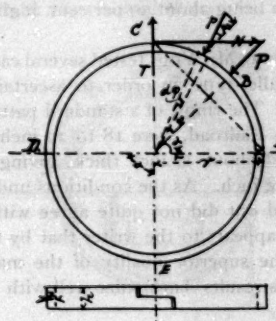


FIG. 3.

The pressure p thus exerted by the compressed ring acts radially and produces a bending moment in the packing ring. In order to determine its value we consider the ring fixed at point *C*, *Fig. 3*, and uniformly loaded with a pressure p. The resultant of the forces acting upon the arc *A B C* may be represented by *P*.

The pressure one ring element has to bear is $p\,h\,r\,d\,\varphi$.

Its component parallel to the resultant *P* is $p\,h\,r\,d\,\varphi\,\cos\varphi$,

while $p\,h\,r\,d\,\varphi\,\sin\varphi$ acts in a direction normal to P. The sum of these components for the quadrant $A\,B\,C$ is expressed by

$$2\int_0^{\frac{a}{2}} p\,h\,r\cos\varphi\,d\,\varphi \quad (1) \text{ and } 2\int_0^{\frac{a}{2}} p\,h\,r\sin\varphi\,d\,\varphi \quad (2)$$

respectively. Equation (2) must be equal to zero, since the components acting upon the arc $A\,B$ are equal to those acting on $B\,C$, but of opposite sign. Therefore equation (1) represents the value of the resultant P and we get finally

$$P = 2\int_0^{\frac{a}{2}} p\,h\,r\cos\varphi\,d\,\varphi = 2\,p\,r\,h\sin\frac{a}{2} \qquad (3)$$

The bending moment acting on cross-section C is equal to

$$M = P\,r\sin\frac{a}{2}$$

or substituting for P its value from equation (3)

$$M = 2\,p\,r^2\,h\sin^2\frac{a}{2} = p\,r^2\,h\,(1-\cos a) \qquad (4)$$

The normal forces ($= N$) and the shearing forces ($= T$) are easily determined by resolving P as shown in the diagram (*Fig. 3*). Their values are

$$N = P\sin\frac{a}{2} = p\,r\,h\,(1-\cos a)$$

$$T = P\cos\frac{a}{2} = p\,r\,h\sin a.$$

In these formulæ angle is the only variable factor. Therefore, in order to calculate the stress in any cross-section, the proper value for a has to be substituted in above formulæ. For various points we have the following values:

TABLE I.

At Point.	a	$(1-\cos a)$	$M=$	$N=$	$T=$
A	0°	0	0	0	0
B	45°	·3	$\cdot3\,p\,r^2\,h$	$\cdot3\,p\,r\,h$	$\cdot7\,p\,r\,h$
C	90°	1	$p\,r^2\,h$	$p\,r\,h$	$+p\,r\,h$
D	180°	2	$2\,p\,r^2\,h$	$2\,p\,r\,h$	0
E	270°	1	$p\,r^2\,h$	$p\,r\,h$	$-p\,r\,h$
A	360°	0	0	0	0

This table shows that the maximum bending moment occurs at point D opposite the cut, where $\alpha = 180°$, and as the normal forces N reach their maximum at the same time, the combined stresses in this cross-section must be considered in dimensioning the packing ring.

From the condition that the external pressure p producing the bending moment M and the internal stresses acting on the same cross-section shall be in equilibrium, we have the relation

$$M = R f_b$$

For a rectangular cross-section is the moment of resistance

$$R = \frac{h t^2}{6}$$

and hence

$$f_b = \frac{6 M}{h t^2}$$

The intensity of direct strain resulting from the normal stress N equals

$$f_s = \frac{N}{h t}$$

and therefore the combined strain at point D according to Table No. 1:

$$f_{max} = f_s + f_b = \frac{2 p r}{t}\left(1 + \frac{6 r}{t}\right)$$

Neglecting the first member the formula may be written

$$f = 12 p \left(\frac{r}{t}\right)^2 \qquad (A)$$

giving results sufficiently close for practical use.

So far the formulæ were derived with the assumption that the curvature of the ring is not changed by compressing it, in order to introduce the piston into the cylinder, *i. e.*, r = constant. This condition, however, is not fulfilled with the Ramsbottom packing ring, as the outside diameter of the free ring is greater than the cylinder bore, and becomes equal to r only after the piston with the rings has been placed in the cylinder.

Let *Fig. 4* represent a part of the free ring, then if $P Q$ and

$P'\ Q'$ are two normal sections at a small distance apart, $C\ G = \rho$ is the radius of the unstrained ring. Through the influence of the bending moment M the particles originally in $P'\ Q'$ will be found in a new plane $P''\ Q''$ still normal to the axis of the ring and their radius of curvature will now be $C'\ G = r$. As a consequence the fibers on the outer side are stretched and those on the inner side compressed. Owing to the qualities of the materials used for packing rings only the stresses which expand the fibers need be considered. Then a layer of fibers ($= h\ d\ y$) at a distance y form the neutral axis, the length of which was

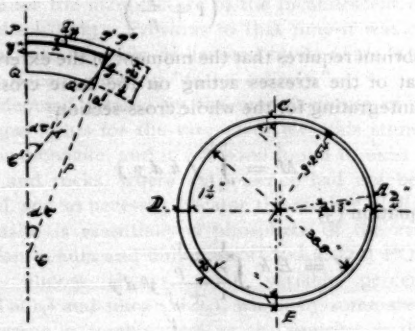


FIG. 4.

originally $(\rho + y)\ d\tau$ has been stretched to $(r + y)\ d\tau_1$, its elongation being

$$(\rho + y)\ d\tau_1 - (\rho + y)\ d\tau = y\ (d\tau_1 - d\tau)$$

Now the elongation λ of a uniform bar of the length L and the cross-section q is directly proportional to the stress P; the resulting unit stress thus $\frac{P}{q}$ is expressed by the well-known formula

$$\frac{P}{q} = \frac{\lambda}{L}\,\mathrm{E} = f$$

E representing the modulus of elasticity of the material. Substituting the proper values for L and λ we get as unit stress in a fiber at a distance (y) from the neutral axis:

$$f = E \frac{y\,(d\,\tau_1 - d\,\tau)}{(\rho + y)\,d\,\tau}$$

or since

$$\rho\,d\,\tau = r\,d\,\tau_1$$

$$f = E\,y \frac{\left(\frac{1}{r} - \frac{1}{\rho}\right)}{\left(1 + \frac{y}{\rho}\right)} \tag{5}$$

Equilibrium requires that the moment of the external forces equals that of the stresses acting on the same cross-section, therefore integrating for the whole cross-section:

$$M = \int_{-\frac{b}{2}}^{+\frac{b}{2}} f\,h\,d\,y\,y$$

or with equation (5)

$$M = E\,h \int \frac{\frac{1}{r} - \frac{1}{\rho}}{1 + \frac{y}{\rho}}\,y^2\,d\,y \tag{6}$$

For larger rings the fraction $\frac{y}{\rho}$ may be neglected without material error, thus putting

$$M = E\,h \left(\frac{1}{r} - \frac{1}{\rho}\right) \int y^2\,d\,y$$

and remembering that $\int y^2\,d\,y$ represents the moment of inertia for a rectangular cross-section $= I$, equation (6) takes the form of

$$M = E\,I \left(\frac{1}{r} - \frac{1}{\rho}\right) \tag{7}$$

(*To be Concluded.*)

Mining and Metallurgical Section.

Stated Meeting, June 9, 1897.

Mr. Benj. S. Lyman, President, in the chair.

MONAZITE.*

By H. B. C. Nitze, E.M.,
Chemist to the Wetherill Concentrating Co., South Bethlehem, Pa.

It has only been within the past few years that monazite has become one of the important economic mineral products, in its use for the manufacture of the incandescent mantles of the Welsbach light. Previous to that time it was considered one of the rare minerals, as denoted by its name, a derivation from the Greek, meaning "to be solitary."

The demand created by the manufacturers of the incandescent gas lights for the rare earth minerals stimulated the search for monazite, and it was soon found to exist in certain deposits and rocks, where its presence had not before been suspected, and so necessity became the mother of discovery.

Monazite is essentially a phosphate of the rare earths, cerium, lanthanum and didymium (Ce. La. Di.) PO_4. It also contains, almost always, small variable percentages of thoria (ThO_2) and silica (SiO_2), which by some are supposed to be present in combination, as an impurity, in the form of thorite or orangite ($Th.SiO_4.H_2O$), while others believe that the thoria is a primary constituent, present originally as the phosphate, either in combination with cerium or as an isomorphous compound, and afterwards altered to the silicate by siliceous waters.

Several typical analyses, made by Prof. S. L. Penfield,* of Yale University, are appended:

*This paper embodies the results, in somewhat condensed and rearranged form, of previous communications by myself, which have appeared in the Sixteenth Annual Report of the United States Geological Survey, 1894-95, Part IV, and in Bulletin No. 3 of the North Carolina Geological Survey, 1895.

*See *American Journal Science*, Vol. XXIV, 1882, p. 250, and Vol. XXXVI, 1888, page 322.

	1.	2.	3.	4.
P_2O_5	28·18	29·28	26·12	29·32
Ce_2O_3	33·54	31·38	29·89	37·26
La_2O_3	28·33	30·88	26·66	31·60
ThO_2	8·25	6·49	14·23	1·48
SiO_2	1·67	1·40	2·85	0·32
H_2O	0·37	0·20	0·67	0·17
	100·34	99·63	100·42	100·15

(1) From Portland, Conn. (2) From Burke County, N. C. (3) From Amelia County, Va. (4) From Alexander County, N. C.

Monazite crystallizes in the monoclinic system. The usual crystal habit is tabular, parallel to the orthopinacoid ($\infty P\bar{\infty}$); also short columnar, and sometimes elongated in small needle-shaped crystals, in the direction of the prism (∞P). The crystals are usually well developed and free from distortion. They vary in size from microscopic needles, having a thickness of only 0·00015 to 0·00062 inch, to the abnormally large and rare crystals that have been found in Amelia County, Va., 5 inches in length. The more usual size, however, lies between 0·05 and 1 inch.

The cleavage is most perfectly developed parallel to the basal pinacoid (oP); it is also distinct, as a rule, parallel to the orthopinacoid ($\infty P\bar{\infty}$), and sometimes parallel to the clinopinacoid ($\infty P\bar{\infty}$).

The mineral is brittle, with a conchoidal to uneven fracture.

The hardness is 5 to 5·5. The specific gravity varies from 4·6 to 5·3. The luster is resinous to waxy, and the crystal faces are splendent in the fresh, pure specimens, and dull in the weathered, impure specimens, the surfaces being sometimes coated with a light brown earthy substance, probably an alteration product.

The purest specimens are transparent, becoming translucent and even totally opaque in the impure varieties.

The color is honey-yellow, amber-yellow, yellowish-brown, reddish-brown and sometimes greenish-yellow.

Monazite is an accessory constituent of the granitic rocks and their derived gneisses. It has been found in these rocks over widely separated regions of the earth's surface, and further search and study is liable to reveal its probable universal

presence in most granites and gneisses. It has also been found in apatite, cyanite, and even in vein quartz. The main constituents of the granitic rocks (quartz, feldspar and mica) all contain the monazite as intergrowths, though it appears to be more generally confined to the feldspar. Zircon may be regarded as a constant accessory, and among the other usually associated minerals may be mentioned garnet, rutile, ilmenite, magnetite, xenotime, fergusonite, gadolinite, sphene, cassiterite, corundum, etc.

Monazite has not been found in the sedimentary rocks, although it may be present in some of these as a re-deposited mineral.

The economically valuable deposits are found in the placer sands of streams and rivers, in the irregular sedimentary sand deposits of old stream beds and bottoms, now covered up, and in the beach sand deposits along certain seashores.

In the Southern, unglaciated countries the decomposition and disintegration of the crystalline rocks, the original source of the mineral, have proceeded to considerable depths. By erosion and secular movement the loose material is deposited in the stream beds, where it undergoes a natural process of sorting and concentration, the heavy minerals, and among them the monazite, being deposited first and together. The richer portions of these stream deposits are therefore found near the head-waters.

The beach sand deposits have a similar explanation, the concentration in this case being brought about by the action of the waves.

The geographical areas over which such workable deposits have been found up to the present time are quite limited in number and extent. In the United States the placer deposits of North and South Carolina stand alone. This area comprises about 2,000 square miles, situated in Burke, McDowell, Rutherford, Cleveland and Polk Counties, North Carolina; and Spartanburg, Greenville and York Counties, South Carolina.

The country rocks are granitic biotite gneiss and dioritic hornblende gneiss. Most of the stream deposits have been

worked for gold. The thickness of the gravel beds is from 1 to 2 feet, and the width of the mountain streams in which they occur is seldom over 12 feet. The percentage of monazite in the gravel is very variable, from an infinitesimal quantity up to 1 or 2 per cent.

In Brazil extensive deposits of monazite occur in the beach sands along the sea coast. The largest of these is on the island Alcobaca, in the extreme southern part of the province Bahia.

Deposits are also found in the gold and diamond placers of the provinces Bahia (at Salabro and Caravellas), Minas Geraes (at Diamantia), Rio de Janeiro and Sao Paulo.

In the United States of Colombia deposits of importance are reported in the gold placers of the Rio Chico, at Antioquia.

In Russia the mineral is found in the Bakakui placers of the Sanarka River in the Ural Mountains; also in the placer mines of Siberia.

In North and South Carolina the monazite is won by washing the sand and gravel in sluice boxes with a stream of water, exactly after the manner that placer gold is worked. The sluice boxes are generally about 8 feet long by 20 inches wide by 20 inches deep. Two men work at a box, the one charging the gravel on a perforated plate fixed in the upper end of the box, the other one working the contents up and down with a gravel fork or a perforated shovel in order to float off the lighter sands. The boxes are cleaned out periodically, depending on the richness of the gravel and the consequent degree of accumulation of the concentrated monazite.

From 40 to 70 pounds of cleaned monazite per box is considered a good day's work.

Sometimes two or more boxes are used, arranged in a series of steps, one below the other.

Magnetite, if present, is eliminated from the dried sand by treatment with a large hand magnet. Many of the heavy minerals, such as zircon, garnet, rutile, ilmenite, etc., cannot possibly be completely eliminated by any means of water separation, owing to the slight differences of their specific gravities.

The commercially prepared sand, therefore, after washing, is not absolutely pure monazite. A sand containing 65 to 70 per cent. monazite is considered a good quality.

Some operators endeavor to clean the water-concentrated sand still further, by pouring it, after it is dried, from a small spout situated in the bottom of a hopper, in a fine steady stream from a height of about 4 feet, on a level platform; the lighter particles (quartz, feldspar, etc.), together with the finer grains of monazite, garnet, rutile, etc. (which might be called tailings), fall on the periphery of the conical pile, and are constantly brushed aside with hand-brushes; the tailings are afterwards re-washed. Instead of pouring and brushing, the material is sometimes treated in a winnowing machine similar to that used in separating chaff from wheat.

Although the grade of the sand may in this way be brought up to 85 per cent. pure, the quantitative proportion is small as compared with the second and other inferior grades, and there is always a considerable loss of monazite in the various tailings.

It is impossible to conduct this washing operation without loss of monazite, and equally impossible to make a perfect separation of the garnet, rutile, ilmenite, etc., even in the best grades. The additional cost of such re-treatment and re-handling must also be taken into consideration.

A marked improvement in the economy and perfection of the treatment would be to size the raw material, separate the quartz and lighter minerals by jigging, and subsequently separate the heavy minerals, garnet, rutile, etc., in the jig concentrates, by passing over a Wetherill magnetic separator.* Experimenting in this direction, I have succeeded in making a practically perfectly clean monazite product, with but an insignificant loss in the tailings.

If the raw material contains gold, it will be collected in the sluice boxes or in the jig concentrates, and it may frequently pay to separate it, which can be readily accomplished by treating the wet concentrates in a riffle box with quicksilver.

The monazite in the stream beds of the Carolina fields has been practically exhausted, and the last mining operations were carried on, for the most part, in the old gravel deposits

*See *Jour. Frank. Inst.*, 143, 279.

and channels of the adjoining bottom-lands. These deposits are mined by sinking pits, about 8 feet square, to the bed rock, and raising the gravel by hand labor to sluice boxes above. The over-lay, which may vary from 3 to 5 feet in thickness, is thrown away, excepting in cases where it carries any sandy or gritty material. The pits are carried forward in parallel lines, separated by narrow tailing banks, similar to the method pursued in placer gold mining.

It has been shown that the monazite occurs in place as an accessory constituent of the country rocks, and that the latter are decomposed to considerable depths, sometimes as much as 100 feet. However, on account of the minute percentage of monazite in the mother rock, it is usually impracticable to economically work it for monazite alone, by such a process as hydraulicking and sluicing, for instance. Where the decomposed rock is gold-bearing, and this is sometimes the case, it may pay to recover the monazite as a by-product. In certain instances the decomposed gneiss, *in situ*, has been found sufficiently rich in monazite to warrant working it.

The value of monazite depends on its percentage of thoria, as this is the element mostly sought after by the incandescent light manufacturers. And, as the percentage of thoria is variable in different sands, the value of the sands is consequently also variable.

The only method for determining the percentage of thoria is by chemical analysis. The fluctuation of the thoria is considerable even in the same locality. It also depends, of course, in a measure, on the degree of concentration of the sand. Some monazite contains practically no thoria. The best Carolina grades carry from 4 to 7 per cent.

The price of Carolina monazite has varied from 25 cents per pound in 1887, to as low as 3 cents for inferior grades and 6 to 10 cents for the best grades, in 1894 and 1895. In 1896, the price fell so far below this mark as to render the mining unprofitable and practically cripple the industry. This was owing to the development and increased output of the Brazilian field, where the sand occurs naturally concentrated on the beach, and requires no cleaning treatment for shipping, after it is dug

out. Being loaded directly into the ships' holds as ballast and transported by water, the freight costs are also considerably less.

In 1893, the output of Carolina monazite sand was 130,000 pounds; in 1894, 546,855 pounds; in 1895, 1,900,000 pounds; and in 1896, for reasons above named, it fell to 17,500 pounds.

CHEMICAL SECTION.

Stated Meeting of April 20, 1897.

Dr. Joseph W. Richards, President, in the chair.

The CHEMISTRY of FOOD ADULTERATION.

[ABSTRACT.]

By Henry Leffmann.

In addressing an audience of professional chemists, I feel that I must deal with this topic from a laboratory point of view only. General considerations would be out of place, as would also be any discussion as to the extent and effect of food adulteration or the legislation needed to limit it.

A marked tendency of modern analytic chemistry is toward uniformity of method. In certain departments this has been brought to a high degree of perfection, the routine of analysis having been developed with much detail, and hence a satisfactory uniformity of results will be attained by different chemists. In many of the departments of food analysis such uniformity has not been secured, and hence differences of results are not infrequent. I may note, however, a special cause of confusion, namely, the uncertainty of standards of purity. In many of the industrial applications of chemistry the analyst has no duty except to state the results in technical form. The interpretation of the data may be left to those to whom the report is made. In sanitary chemistry, however, there may be a wide margin for "inferences," and two chemists may differently interpret the same analytic figures. Sometimes an arbitrary rule is established either by the influence of some espe-

cially prominent scientific authority, or by official, *i. e.*, legislative, decision. These points are well illustrated by the now numerous laws applicable to milk adulteration. Not only are the methods of analysis somewhat variable, but an attempt also is made to fix an arbitrary standard below which all milk shall be deemed to be adulterated. This standard is not the minimum, as found by comparison of a large number of samples, but is fixed above that, under the assumed right to encourage the production of a high-grade article. Moreover, when milk analyses are reported it is not uncommon to affix a calculation of the "added water." This is based on a purely arbitrary assumption, namely, a minimum limit of solids—not fat. I contend that no chemist is justified in such an assumption. When a statement is made in court to the effect that a milk sample showed "10 per cent. of added water," the jury and all persons not familiar with milk analysis are led to believe that the water has actually been detected as such, whereas it is merely an arithmetic inference based upon an arbitrary assumption. Actual experience shows that in many cases milk just as taken from the cow would show a considerable percentage of "added water" by the methods of calculation now in vogue. The object of chemistry is the ascertaining of facts, not the encouragement of the breeding of high-class cattle.

A minuteness of routine is often needed to secure uniformity and comparability of results, but this minuteness must be more than a mere form. In some cases attention to minute detail is prescribed, although the processes are inherently approximate only. Such criticism, for instance, may be brought against the "official process" for the determination of the volatile acids in fat. The total amount of volatile acids cannot be obtained by the method, and the percentage present in normal samples of butter varies within wide limits. The practical purpose for which this process is used, namely, the detection of the admixture of foreign fats with butter, can be attained with certainty without the minute routine prescribed and the variations in normal butter far exceed the errors of experiment, even when the process is conducted somewhat roughly.

Another important point is the want of uniformity in the

statement of results. Some of the data in analytic statements are not infrequently obtained indirectly, or by difference, and these facts should be in some way indicated in the report. In a State official report published some years ago, a list of many analyses of iron ores is given, the figures in each analysis adding up to exactly 100. It is obvious that some ingredient was determined by difference, yet there is no indication of this in the tables. In a neighboring State, reports on milk analysis are frequently made, which give separate figures for the fat, sugar, proteids and ash, and no information is given as to which of these ingredients are determined directly. If any ingredient is determined by difference, it should be stated; on the other hand, if all had been determined directly, there should have been a special determination of total milk solids as a control.

In water analysis there is much to be criticised, as regards the methods of stating results. Water analysis differs from most other analytic work, in that the results are never expressed in percentages, and hence has arisen much variety and irregularity of statement. At the present day, four forms of statement are used: grains per United States gallon, grains per imperial gallon, parts per million, and parts per hundred thousand. Some chemists, in the United States and England, use two methods in the same analysis, stating most of the ingredients in grains per gallon, but using parts per million (or per hundred thousand) for the so-called "ammonias." This is highly absurd, and it is surprising that anyone should adopt it. Its perpetuation is doubtless largely due to slavishly following Mr. Wanklyn, whose work in this field has been a curious medley of the ingenious and preposterous. When a statement of an analysis of water contains such data as sulphuric acid, carbonic acid, phosphoric acid or nitric acid, there is a vagueness which will closely interfere with a close calculation of results. Does the chemist mean by sulphuric acid, SO_3, SO_4 or H_2SO_4? Similarly, does carbonic acid mean CO_2, CO_3 or H_2Co_3?

The main object of furnishing the actual figures of a water analysis is to place on record the facts and to permit of the formation of an independent judgment, and it is in this

light that we must proceed when we frame a method of statement. There is no reason why our methods of statement should not conform to the highest requirements of modern theories. It is often impossible and generally difficult to determine exactly how the various elements constituting the mineral residue of water are combined. Chemists follow certain conventional methods, based on probable controlling affinities, each case being in a measure decidedly independent, but in fairness these statements ought to be accompanied by information that the arrangement is largely supposititious. The proper way is to give a list of the individual elements or radicals, and thus permit any one familiar with the subject to re-calculate the data as deemed advisable. I consider it highly inadvisable to state any element in terms of a combination that cannot possibly exist in the water. We see much incongruity in reporting the very important data of the various conditions in which nitrogen exists in water. This element may occur in water in five states, namely, free and as nitrite, nitrate, ammonium and so-called organic compounds. The free nitrogen has little significance. Many valuable inferences may be drawn by the proper estimation of the last four forms. The brilliant work of Mr. Wanklyn has given a world-wide prominence to the last two data, and has fastened upon them two highly inappropriate titles. The nitrogen existing as ammonium compounds he called "free ammonia," which it is not; and the nitrogen obtained by his method from the organic matter he called "albuminoid ammonia," an equally inaccurate term. A still more absurd system has frequently been adopted for expressing the oxidized nitrogen; that is, that existing as nitrites and nitrates. The probability is that calcium nitrite and nitrate are the forms of combination usually present, certainly the acids themselves do not exist as such. Yet it is not uncommon to see the oxidized nitrogen expressed in terms of nitrous and nitric acid, which is as ridiculous as if a chemist would report the carbon in steel in terms of carbonic acid, or the silver in an ore in terms of silver nitrate.

The proper method of expressing the data of a water analysis is in terms of the elements and ascertained radicals present.

This commits the chemist to no theory, but allows any one to recalculate the data according to conventional methods of individual preference. Such a plan has the advantage of presenting the combined nitrogen so as to permit immediate judgment as to the ratio between the different conditions, a point that is of especial advantage in tabulating comparative results.

Uniformity in methods of analysis is highly desirable, but it is difficult to secure the consent of all chemists to some processes. A partial benefit will be gained if the methods are indicated in some manner in the report.

Stated Meeting of May 18, 1897.

NOTES ON THE DETERMINATION OF INSOLUBLE PHOSPHORUS IN IRON ORES.

[ABSTRACT.]

By Charles T. Mixer and Howard W. DuBois.

The authors referred to the greater necessity than formerly of determining the insoluble phosphorus in Bessemer iron ores, owing to the increasing demands for a lowering of the phosphorus content in what are considered standard Bessemer ores.

The usual method of fusing the insoluble residue with sodium carbonate has been found impracticable where a large number of determinations are to be made daily.

Experiments were instituted to devise a shorter method that would give accurate results.

The use of hydrofluoric acid to dissolve the siliceous residue from the acid treatment of the ore was found to be of no advantage as regards economy of time.

A mixture of ore and sodium carbonate subjected to a red heat (without producing a fusion) gave fair results with low silica ores, but was not adapted to high silica ores on account of the fusion of the mass.

Calcined magnesia mixed with the ore and ignited to a red heat (without fusion) extracted all the phosphorus, even with high siliceous ores.

Calcining the ore (without the admixture of any base) gave perfectly accurate results.

The calcination of the insoluble residue was just as satisfactory, so this treatment was adopted.

The details of the method are as follows: About 1½ grams of ore are dissolved in a No. 3 beaker with 25 cubic centimeters of hydrochloric acid, 1·1 specific gravity. When the ore is dissolved the excess of acid is evaporated until the solution begins to assume a syrupy consistency. It is then diluted with water and filtered into an Erlenmeyer flask, and the filter-paper and residue are placed in a platinum crucible and ignited. When the paper is burned off the residue is broken up with a platinum rod and ignited at a red heat for several minutes, when it is removed and placed in a beaker for solution. Water is added, together with a few drops of hydrochloric or nitric acid, and the solution is brought to gentle boiling for about five minutes. It is then filtered into the flask containing the soluble phosphorus (or into another flask, in case it is to be determined separately*) neutralized with ammonia and precipitated as ammonium phospho-molybdate. The latter precipitate is titrated according to Handy's modification of the sodium hydroxide method.

[A table of analyses of some eighteen different ores was shown, in which the proposed method was checked up by the standard method.]

The conversion of the insoluble phosphorus into the soluble form, by simple ignition, is a matter of some theoretical interest. Possibly the method proposed by Berzelius for the decomposition of phosphates by means of silica may involve a reaction somewhat similar to it.

*It has been found that it is better to determine separately the soluble and insoluble phosphorus. Otherwise a too dilute solution is obtained for the precipitation.

A CRITICAL REVIEW OF THE METHODS OF DETERMINING MINERALS.

By Dr. Joseph W. Richards,
Of the Department of Metallurgy and Mineralogy of the Lehigh University, President of the Section.

The determining of a mineral consists in finding out its species, and in doing this so conclusively as toprove that it is the species named to the exclusion of all other similar related minerals.

The question must be met at the outset: "What constitutes a mineral species?" I will answer by quoting our one-time professor of chemistry at the Institute—Dr. Persifor Frazer—whose word in geology and mineralogy carries with it the weight of an authority. Says Dr. Frazer: "Every true mineral is a definite chemical compound or element, homogeneous throughout its parts, and capable of expression in a formula. Its molecule is a distinctive whole—the unit of its mass—and incapable of division as long as the mineral retains its characteristic properties."

It is one of the easiest things in the world to accept the present scientific definition and to forget the laborious steps by which such an apparently simple conclusion was evolved. Dr. Frazer's definition appears to us so nearly self-evident that it is difficult to realize that eighty years ago mineralogists were hotly debating the question as to whether the identity of a mineral consisted in its chemical composition or in the sum total of its physical properties. Thence arose two schools of mineral classification. Werner and his followers adopted the natural-history method of classification on the basis of physical properties alone, and prided themselves on having achieved a classification entirely independent of any aid from chemistry. The other school, of which Berzelius was one of the founders, insisted on the chemical composition as the basis of a proper classification, but were not so exclusive as the other school, and admitted physical distinctions, particularly that of form (*i. e.*, crystallization) into their smaller subdivisions.

It will help, in our further consideration of the subject, to examine more closely these two schemes, particularly the Wernerian.

Cronstedt, about 1750, divided the mineral kingdom into four great divisions, viz.:

I. Earth and stones.	III. Combustibles.
II. Salts.	IV. Ores.

Werner, the first of the illustrious teachers of mineralogy at Freiberg, adopted this division and extended it greatly. He divided the first order into nine genera, as follows:

EARTHS.

1. Zirconian.	5. Calcareous.
2. Siliceous.	6. Barytic.
3. Aluminous.	7. Strontian.
4. Magnesian.	

STONES.

8. Diamond.	9. Hallites.

Here, indeed, it would appear that the classification was nothing less than purely chemical, yet it was not. A certain number of external characters which siliceous minerals, for instance, usually exhibit being assumed as generic characters, or as a type of the genus, every mineral possessing those characters, whether it contains any silex or not, is arranged under the siliceous genus. And so with the other of the nine genera. Under these principles, Werner saw no inconsistency in placing sapphire in the siliceous genus and opal in the aluminous. I need not expatiate on the absurdity of this procedure from our modern standpoint, but it is only the stupendous development of chemical investigation in recent years that has lifted mineralogy out of that confusion.

Salts, according to Werner, included only such minerals as have some taste and a considerable degree of solubility in water; and they were divided into carbonates, nitrates, muriates and sulphates.

Combustibles were divided into sulphur, bitumen, graphite and resin.

Ores were divided into as many genera as there were distinct metals found as ores. Thus, all the iron ores constituted one genus. The genera were divided into species, depending on their external characters. This was a true chemical basis to start with, but far inferior to the classification according to the acid ingredient instead of the base.

The key-note of this system is found in the following quotation from Werner himself: "Whenever the external characters and the chemical composition are *at variance*, the species is determined solely by *the external characters*." According to this method of reasoning, gypsum and selenite were classed as different species because they looked different, although of exactly the same composition, while calamine and smithsonite were classed together as one mineral because they looked alike, although of very different composition.

Coming to the chemical systems of classification, they were far from being above reproach, yet they showed fewer inconsistencies than the other method. Many mistakes were made, it is true, principally owing to the imperfect state of chemical science. The phenomena of di-morphism were yet awaiting the light of Mitscherlich's genius for their explanation, and the reproach was cast on the chemical method that it had to classify together calcite and aragonite as one species, while everybody knew they were different. Many were the hours spent by zealous adherents of the chemical side, in trying to establish by analysis some essential difference between calcite and aragonite and thus to silence their opponents. Mitscherlich's researches on iso-morphism and di-morphism, however, cleared up so many of these difficult points that in 1841 Rammelsberg was able to resuscitate the almost defeated chemical method and to champion it so effectively as to have made it the present accepted basis of mineral classification.

A very striking example of this change of base in mineral classification is shown in the successive standard American works on mineralogy. Shepard's work, issued in 1835, 1844 and 1857, in successive editions, was on the natural-history method. J. D. Dana's first edition, in 1837, followed the same system; the second edition, in 1844, was similar, but described

in an appendix Rammelsberg's chemical system; the third edition, in 1850, discarded the natural-history method of classification, and adopted altogether the chemical method. This has been retained in all subsequent editions of this magnificent work, which has become not only the American authority on mineralogy, but, one may almost say, the international authority. The importance of this classification to our discussion merits that it be given at once, in outline, as follows:

DANA'S CLASSIFICATION OF MINERALS.

I. Native elements.
II. Sulphides, arsenides, antimonides, selenides and tellurides.
III. Chlorides, bromides and iodides.
IV. Fluorides.
V. Oxygen compounds.
  (1) Oxides.
  (2) Ternary oxygen compounds, or oxygen salts.
    1. Silicates.
    2. Tantalates and columbates, etc.
    3. Phosphates, arsenates, vanadates, etc.
    4. Borates.
    5. Tungstates, molybdates, chromates, etc.
    6. Sulphates.
    7. Carbonates.
VI. Hydrocarbons.

It is now proper to inquire into the subject of the identification of a mineral, *i. e.*, its determination.

The question is, how to most quickly, easily and surely identify an unknown specimen. This is not exactly the same sort of question as the one of classifying properly a mineral after it is completely described; they are two aspects of the same problem, but from different points of view; for, as Dr. Sterry Hunt has said: "A natural system of classification is not subordinate to the end of identifying species, but should consider objects in all their alliances and relations." Systems for identifying species are not therefore *necessarily* along the identical lines of mineral classification. However, the natural-

history method of classification by outward characters adapts itself very readily to schemes of identification in which the physical properties are given the pre-eminence in determining the mineral. Determinations of hardness, streak, luster, gravity, fusibility, form, etc., are easily made without any special training, and therefore are most useful to beginners in the science of determining minerals. The chemical system of classification, however, at once suggests chemical analysis as the true basis of a determinative method, and lends itself most kindly to that means of identification. Moreover, the methods of chemical analysis, particularly those of blow-pipe analysis, have developed coincidently with the growth of the chemical classification of minerals.

The postulate may be made, that if every mineral species is a definite chemical compound, then the true basis of identifying the mineral should be the chemical analysis. In many cases this may not be the quickest way, but it is bound to be the surest. But, shall we throw away all the aid to be derived from physical tests? By no means. If from the properties at once evident on casual inspection memory suggests a familiar mineral, let chemical analysis at once come in to confirm or deny the determination. *In the great majority of cases, the physical determination is practically valueless without the analytical confirmation;* and there are very few cases in which the chemical confirmation is absolutely unnecessary or useless. On the other hand, whenever a mineral is not at once recognized on inspection, the true basis of search to determine it should be to fix as nearly as possible its composition by chemical analysis, and then to utilize physical tests to distinguish between minerals difficult or impossible to separate by differences in their composition.

Tables based entirely on physical tests have been constructed; mixed tables, based on a combination of both physical and chemical tests have been devised; I have preferred to attack unknown minerals *entirely* from the chemical side, and will later on explain what appear to me the advantages of this method.

It is, of course, superfluous to analyze in detail every one of

the numerous schemes of determinative mineralogy which have been constructed; it will suffice to select a few typical examples, and to discuss them on general principles.

Dana gives in an appendix to his text-book on mineralogy one set of tables based primarily on the crystal system, then on luster (metallic and non-metallic), and then with the minerals arranged according to specific gravity. This classification is very useful if the mineral shows clearly its crystallization, and is truly of the system which it appears to be; but every mineralogist knows that minerals are oftener uncrystallized than crystallized, and that in probably one case out of three the system is not what it appears to be. The question of luster may sometimes mislead. The specific gravity may be depended upon in probably three cases out of four. Summing up the probabilities that a mineral could be identified by the use of such a table, they are about one in two if the specimen is crystallized, and not more than one in ten if it is uncrystallized. In scarcely any case would the identification be completely satisfactory without the chemical confirmation.

A set of tables in more extensive use than Dana's, and based also on physical tests alone, is that of Dr. Weisbach, well known in English by Dr. Frazer's translation. The following outline shows the scheme of this classification:

WEISBACH'S TABLES.

I. Minerals with metallic luster.
   1. Red. 2. Yellow. 3. White. 4. Gray. 5. Black.

II. ——— of sub-metallic or ordinary luster, and with colored streaks, as follows:
   1. Black. 2. Brown. 3. Red. 4 Yellow. 5. Green. 6. Blue.

III. ——— of ordinary luster, with white or gray streak.
   1. Very soft. 2. Soft. 3. Semi-hard. 4. Hard. 5. Very hard.

Supplementary table for Class III:
   A. Soluble in water.
   B. Effervescing in HCl (carbonates).

C. Not soluble in water or containing CO_2.
1. Containing water—Easily fusible to infusible.
2. Anhydrous—Easily fusible to infusible.

In using these tables, if there is no question as to the luster, or color, or streak, or hardness, that is, if all these properties are normal and observed correctly, the specimen thereupon falls into a class varying in number from five to sixty-three, among which it is to be distinguished by a critical comparison of its other physical properties. In the case of the class of five, this is an easy matter; in the majority of cases, the classes averaging thirty to fifty, this is an arduous or impossible task. We have further to consider that sometimes the luster is doubtfully metallic, frequently the color is not easy to judge, that the streak is often misleading and, most of all, the hardness very seldom to be relied upon. I should say in all fairness, taking all these points into consideration, that a careful observer would not place more than fifty out of one hundred promiscuous specimens in the class to which Weisbach assigns them, and, out of those fifty correctly classed, would not be able to identify over twenty-five with any reasonable degree of certainty without having recourse to the chemical composition for confirmation.

One of the best examples of tables based on mixed physical and chemical tests is that of Von Kobell, which is the basis of the classification so well-known and largely used in the United States, viz.: Brush's. They are as follows:

VON KOBELL'S TABLES.

I. Metallic luster.
a. Native malleable metals and mercury.
A. Fusible at 1 to 5 or easily volatile, containing: 1. Arsenic. 2. Selenium. 3. Tellurium. 4. Antimony. 5. Sulphur. 6. None of these.
B. Fusible above 5, or infusible, not volatile.
1. Containing manganese. 2. Magnetic B. B. 3. All others.

II. Without metallic luster.
  A. Easily volatile or combustible.
  B. Fusible at 1 to 5.
    (I) Reduces to metallic button, or magnetic B. B.
      1. Silver. 2. Lead. 3. Copper {with As. / no As.
      4. Cobalt. 5. Magnetic B. B.
      6. All others.
    (II) Not belonging to (I).
      1. Alkaline after ignition.
      2. Soluble in HCl without residue.
      3. Soluble in HCl, with gelatinous residue.
      4. Soluble in HCl, with sandy residue.
      5. Insoluble in HCl, has Mn.
      6. All others.

I. Metallic luster.
II. Without metallic luster.
  A. Easily volatile or combustible.
  B. Fusible at 1 to 5.
  C. Fusible above 5, or infusible.
    1. With cobalt nitrate show alumina.
    2. With cobalt nitrate show zinc.
    3. React alkaline after ignition.
    4. Soluble in HCl, contain no silica.
    5. Soluble in HCl, contain silica.
      (1) Hydrous.
      (2) Anhydrous.
    6. Not belonging to the foregoing divisions.
      (1) Hardness under 7.
      (2) Hardness 7 or over.

It will be seen that the basis of this classification is primarily and secondarily physical, afterwards chemical composition plays an important part. The superiority of this method over the previous ones based solely on physical tests, *lies almost altogether in the extent to which the chemical tests are introduced.* There is still some uncertainty as to luster being correctly determined, and considerable uncertainty is introduced by the

factor of fusibility where it lies anywhere near to five; but, granting that these are correctly determined, then the chemical tests are reached and the uncertainties mostly cease. No one worthy of being called a chemist can mistake sulphur for selenium, or silver for lead; the identification of such characteristic elements is practically a certainty. With such chemical tests as solubility in hydrochloric acid, with a gelatinous or sandy residue or no residue at all, there is still considerable room for uncertainty, and the scheme is weak in proportion as they are introduced.

Dr. Fuchs introduced mixed tables based primarily on chemical composition, and to that extent superior to Weisbach's. As a whole, I have found these tables (or subsequent ones based upon them) to be the most satisfactory tables published. To observers skilled in blow-pipe analysis they furnish the most satisfactory means of identification of an unknown specimen. The scheme is as follows:

FUCHS' TABLES.

(*By the Blow-pipe.*)

I. Heated B. B. on charcoal.
   1. Volatilizes or burns. 2. Arsenic fumes { metallic. / non-metallic.
   3. Selenium fumes. 4. Shows antimony.
   5. Shows tellurium. 6. Reacts alkaline { soluble. / non-soluble.
   7. Residue magnetic.

II. Reduced B. B. with soda, on charcoal.
   1. Reacts for sulphur and gives metallic button.
   2. Reacts for sulphur and gives no metallic button.
   3. No sulphur reaction, but gives metallic button.

III. Shows manganese in the beads { metallic luster. / non-metallic luster.

IV. Shows zinc with cobalt solution.

V. Soluble in HCl, without residue.
   1. Fusible B. B. (a) Hydrous. (b) Anhydrous.
   2. Infusible B. B. (a) Hydrous. (b) Anhydrous.

VI. Soluble in HCl, to a jelly (silica).
(Classified similarly to V).
VII. Soluble in HCl, with separation of silica (no jelly).
1. Hydrous. 2. Anhydrous.
VIII. Insoluble in HCl, but bead test shows silica.
1. Fusible B. B. 2. Infusible B. B.
IX. Belonging to none of the previous divisions.

The weakest point of these tables is in the action of hydrochloric acid, where there is room for some uncertainty, and where tests for the elements, as in the previous divisions, are generally much more satisfactory. Division IV should also be abolished, and placed as a fourth sub-division of II, for by reducing with soda and a little borax on charcoal, zinc is more certainly identified than by the cobalt nitrate test. Cadmium minerals could also have been included under the same subdivision. Taking these tables altogether, I would call them the most satisfactory of the published tables.

I will end this review by describing the methods of determinative mineralogy taught at the Lehigh University, and which my ten years' experience has proven the most certain way of teaching a student to identify minerals.

First of all, the basis is the chemical identification, but with the aid of physical tests brought in at the most profitable stage of the inquiry.

The observer is to first examine the specimen carefully, noting everything that is to be seen or observed by the most simple tests, such as approximate hardness and streak, but not to spend any length of time, more than a minute or two, at such observation. The object of this casual inspection is to determine whether the mineral is similar to any that the observer has seen before; if it is, and therefore suggests one or even several species, the observer is immediately to make a confirmatory test, preferably chemical, and as general as possible, to see if it can possibly be what is suspected. If the test is affirmative, then other confirmatory tests must be applied, with the particular purpose of excluding all related minerals of closely allied composition. If the test is negative, and no other mineral or minerals suggest themselves, then the

general method of procedure, based solely on chemical composition, is to be followed.

As an illustration, suppose a mineral appears on casual inspection to be wavellite. The first test is to determine whether it is a phosphate or not. If it is, then alumina, water and finally fluorine can be tested for to complete the identification. If not a phosphate, it may have been observed that the mineral glowed strongly and gave a calcium flame, which would suggest *aragonite*, and a test for carbonic acid would be in order. Or, it might have been observed that it fused easily, thus suggesting a radiated zeolite, and tests for silica and water would be in order. If none of these were observed, then the mineral would have to be attacked along broader lines, but if any of these tests have resulted affirmatively, then the observer has profited by his previous knowledge to obtain a short cut to the identification of the specimen. It is evident that the wider the observer's previous acquaintance with numerous varieties of numerous species, the more he will profit by his experience and be able to put it to use in identifying the specimen.

If the observer has no definite idea, from this casual inspection, of what the mineral may be, or if the ideas given by casual inspection were negatived by the confirmatory tests, then some regular outline of procedure must be followed, and the following outline is offered as having been used very successfully for several years by your lecturer. Leaving aside the first three items, as being intended for identifying a few simple mineral species, clearing the ground, so to speak, the real classification begins at IV. All the species included in I, II and III are included in the later classes.

The outline is as follows:

LECTURER'S METHODS.

I. If metallic and malleable, look for native metals.

II. If very light and black, examine for hydrocarbons.

III. If it has a taste, examine for chlorides, nitrates, sulphates, etc.

IV. If of metallic, adamantine or resinous luster, test in the *open tube for S, As, Sb, Se, Te.* If present, roast thoroughly and test by beads, flame and reduction.

V. If of any other luster, or if no test is obtained in IV, make *bead test for silica*. If present, make flame test, etc.

VI. If silica is absent, test for phosphates and borates. If test is obtained, make bead test, reduction, etc.

VII. If P and B are absent, test for carbonates. If test is obtained, make flame test, beads, reduction, etc.

VIII. If CO_2 is absent, test for sulphuric acid. If test is obtained, make flame test, beads, reduction, etc.

IX. If SO_3 is absent, test with $KHSO_4$ for volatile acids. If test is obtained, make flame test, beads, etc.

X. If volatile acids are absent, make test IV (open tube), if it has not previously been made.

XI. If open tube has already shown nothing, make the bead tests very carefully, to find the weaker acids, such as Cr, V, U, Ti, Mo. If present, make any other tests.

XII. If weaker acids are absent, substance is probably an oxide. Make any blow-pipe tests not already made.

It will be observed that the outline follows generally the broad lines of the classification of mineral species used by Dana, the primary idea being to class the mineral first by finding its acid constituent. This has the disadvantage of bringing most of the oxides and native metals last in the classification, and makes it desirable that the observer be well-informed with those classes by previous acquaintance, as thus much time is frequently saved. If there is any doubt about the luster, the testing begins at IV; if the luster is certainly not of the kinds therein named, it is best to begin at once at V.

In testing for the acid ingredient, those are tested for first which are most likely to be present (other things being equal), and also those tests are made first which are the quickest to make (other things being equal). Thus, silica is tested for before carbonic acid, because the silicates are more numerous; while phosphates are tested for before carbonates, because the test takes less time.

After an acid is found, the direction of the testing is towards the basic ingredient. It should be observed, however, that if the tests at any time give in any way such information about the mineral that the observer suspects what it is, then

let him at once leave the general outline, and by direct tests confirm or deny his suspicion. If, for instance, when testing for phosphorus the barium flame is seen, and the observer then looks at the mineral again and suspects *barite*, then he should test at once for sulphuric acid to affirm or negative his suspicion, without going through the form of testing for carbonic acid. If sulphuric acid is absent, then let him take up the scheme again where he left it, and test in regular order for carbonic acid.

By following these directions, the composition of a mineral, or at least one acid and one base present, can quickly be found. The question then arises, how many minerals can contain the ingredients so far found, and in order to facilitate the search for minerals containing certain elements, I have prepared tables of minerals arranged according to the elements they contain. These tables contain under the heading of each element a classification of all the minerals containing that element, arranged primarily according to the acid ingredients, in the order in which they would be found when following the outline of procedure I have indicated. Under each acid, the minerals are further classified according to the other constituents which may be present, arranged in the order in which they are most quickly and surely identified by blow-pipe tests, followed by these minerals containing only the acid and the base, or possibly containing some other ingredients not recognizable by blow-pipe tests. Wherever, as often happens, a list is obtained of several minerals containing exactly the same ingredients, a small table of physical properties placed to the right gives the means of distinguishing them apart. A sample page is as follows:

LECTURER'S TABLES (sample page).

Copper.

Physical Properties, Compositions, etc.

Sulphates:

With Pb:
- † Cl: Caracolite.
- † Fe: Beudantite.
- * : Caledonite, linarite.

With Zn:
- † Al: Aluminite (impure).
- * : Serpierite.

With Fe:
- † Al: Cyanotrichite.
- * : Phillipite, pisanite.

With U:
- † Ca: Uranochalcite.
- * : Voglianite, johannite (H_2O—5 per cent.).
- : Zippeite (H_2O—16 per cent.).

With Na:

With K:

With Ca:

With Cl:

With H_2O:

* * :

It will be observed that, granting that the experimenter has found sulphuric acid and copper, if he does not at once identify the specimen by that information, his next step should be to reduce with soda for lead and zinc; if lead is found, then tests for chlorine or iron are in order, and if neither of these be present, the mineral must be caledonite or linarite, which must be told apart by reference to their physical properties. If the reduction with soda has shown nothing, the bead test for iron and uranium is in order. If these are absent, the flame test for sodium, potassium and calcium is to be made, and if these are absent, the special test for chlorine and then water. If none of

these are present, the mineral will be found in the list following the double asterisks, and distinguished in that list by its physical properties. (The names of these latter minerals, and the physical properties, are omitted in this sample page for lack of space.)

It will be objected to this method that with minerals which may contain small amounts of many ingredients their classification will be very difficult. This is admitted, but by classifying these minerals under each heading that they can possibly come, as well as under that heading where they must invariably come, the careful observer cannot fail to identify them, no matter what known variety of composition they may show.

The essential idea of this method of working is to use the physical properties as suggestive or confirmatory—*suggestive* on casual inspection of what the mineral may be, such suggestion to be confirmed by chemical tests; *confirmatory* after a determination by chemical tests. Conversely, the chemical properties or composition are used as the true *determinative* factors, to which the physical tests are subsidiary or confirmatory. Several years' practical use in the mineralogy laboratory has demonstrated, as far as my experience goes, the superiority of this method of determination, both in reliability and, taking the average, in quickness.

[At the close of the lecture there was shown a portable specific gravity hydrometer, made by Wood & Comer, of Philadelphia, with especial reference to the use of the mineralogist, and which gives rapidly and accurately the specific gravity of pieces weighing not over 1 gram. Its use in the laboratory work at Lehigh University has demonstrated this claim, and shown that it meets the present need for a cheap, portable and accurate instrument for determining specific gravities.]

Lehigh University, Bethlehem, Pa., June 15, 1897.

IN MEMORIAM.

JOHN HALDEMAN COOPER.

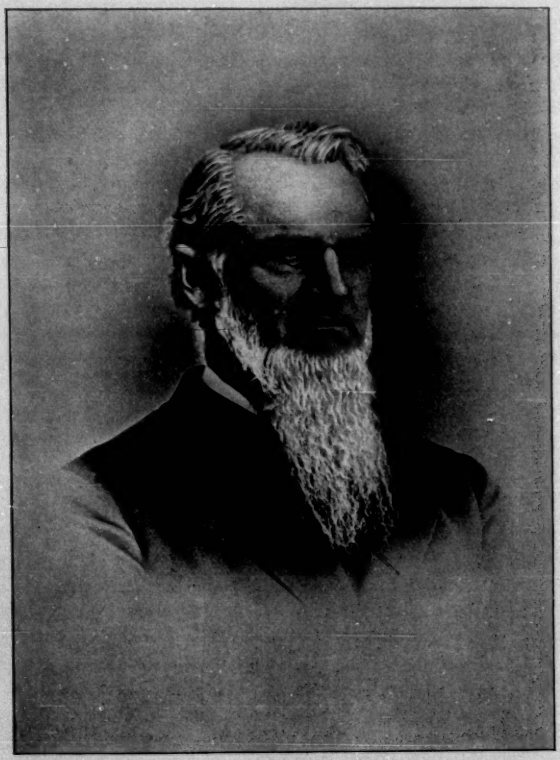
John Haldeman Cooper was born at Columbia, Lancaster County, Pa., on the 24th of February, 1828, and died at his home in West Philadelphia, on the 9th of May, 1897.

His parents were members of the Society of Friends, and Mr. Cooper remained a member of this body throughout his life. His education and early experiences were obtained under the humble conditions usual in the rural villages of the time.

Those who knew him in his youth recall the mechanical instincts and inventive talents of the boy, and his ardent desire for knowledge, as well as a trait of sturdy integrity, in all of which the boy was father to the man. After a short sojourn in Baltimore, he came to Philadelphia in 1852, and after several years of struggling under adverse circumstances, he established a firm reputation as a reliable and conscientious mechanical engineer.

Shortly after the outbreak of the civil war, he was engaged by I. P. Morris & Co. During his service with them, he had charge of the installation of machinery in the United States monitors *Lehigh* and *Sangamon*, also the *Monadnock* and *Agamenticus*. His work at that period is remembered by his associates for the care and attention given by him to every detail of the work, which was completed without an error. He devised a system of symbols which facilitated correspondence, and aided the workmen in the selection of parts, and subsequently became standard to some extent at the works.

Towards the close of the war, Mr. Cooper was engaged by Jacob Naylor, as superintending engineer of the "People's Works," and during the subsequent fifteen years the results of his efforts were indelibly impressed on the products of that establishment. Amongst other noteworthy work, he produced the best, if not the first, examples in Philadelphia of stationary compound engines, some of which are giving satis-



JOHN HALDEMAN COOPER.
(1828–1897.)

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factory service to-day. In 1881, Mr. Cooper went to California, on account of his health, which had become impaired, remaining there for three years. In 1884, the Southwark Foundry and Machine Company, of this city, engaged him as superintending engineer. His first work there was the centrifugal pumping plant for the United States Navy Yard at Mare Island. This machinery was of unprecedented magnitude of its class in this country, and involved considerable study and research. The result of Mr. Cooper's labors was a pumping system, which largely exceeded the estimates for capacity, and which has served as a model for similar machinery since procured by the Government. For the past six years Mr. Cooper has been engaged as a consulting engineer and mechanical expert, latterly with the firm of H. R. Worthington, in connection with their cooling tower condenser.

Mr. Cooper became a member of the Franklin Institute in 1856, and served on the Board of Managers from 1870 to 1873, inclusive. He was elected a member of the Committee on Science and the Arts in 1890, and served until his death. His work on this committee was conspicuously conscientious and thorough. His reports on the R. I. compound locomotive and on the Pelton water-wheel were exhaustive historical researches of great merit; and both were published in the *Journal* and largely quoted at home and abroad. His contributions to the *Journal* were numerous, extending at intervals through the series, from volumes 87 to 140, and covered a variety of topics. One of the series, devoted to the subject of belting was subsequently published as a treatise, which passed through several editions, and formed an exhaustive citation of references and opinions on the subject.

Mr. Cooper was a genial, undemonstrative man, who made warm friends, who always held him in sincere regard. He was an indefatigable student and collector of facts, both ancient and modern, relating to his profession. His fund of information and experience was always at the service of others. His liberality in this respect was exceptional, and is remembered with gratitude by many of his friends.

In 1854, Mr. Cooper married Elizabeth Yerkes, who

survives her husband and their two children, who died several years ago.

JAMES CHRISTIE,
H. R. HEYL,
WASHINGTON JONES.

NOTES AND COMMENTS.*

EUROPEAN ELECTRIC RAILWAYS.

L'Industrie Electrique has just published a complete list with details of the electric railways now operating on the continent of Europe and in Great Britain. From these data it appears that Germany is far ahead of any other European country, in both the number of electric railways and length of mileage. Germany also has four roads using storage batteries, and France five such roads. Switzerland also makes a very good comparative showing, viz.:

	Total Length of Lines in Kms.	*Total Power in K. W.*	*Number of Motor Cars.*	*Lines with Atr. Cond.*	*Lines with Undergr. Cond.*	*Lines with Centr. Rail.*	*Lines with Accum.*	*Total No. of Lines.*
Germany	642·69	18,963	1,631	45	2	.	4	51
England	109·42	4,670	168	10	1	6	1	18
Austria-Hungary	83·89	2,589	194	7	2	.	1	10
Belgium	34·90	1,220	73	4	1	.	.	5
Bosnia	5·60	75	6	1	.	.	.	1
Spain	47·00	600	40	3	.	.	.	3
France	279·36	8,756	432	19	1	1	5	26
Holland	3·20	320	14	.	.	.	1	1
Ireland	18·00	486	32	1	.	1	.	2
Italy	115·67	5,970	289	9	.	.	.	9
Sweden-Norway	7·50	225	15	1	.	.	.	1
Portugal	2·80	110	3	1	.	.	.	1
Roumania	5·50	140	15	1	.	.	.	1
Russia	14·75	870	48	2	1	.	.	3
Servia	10·00	200	11	1	.	.	.	1
Switzerland	78·75	2,622	129	17	.	.	.	17
Totals	1,459·03	47,596	3,100	122	8	8	12	150

From the Secretary's monthly reports.

BOOK NOTICES.

Entwicklung, Bau u. Betrieb der Elektrischen Öfen, zur Gewinnung von Metallen, Carbiden u. anderen metallurgisch wichtigen Produkten. Von Dr W. Borchers, Lehrer a. d. Königl. Maschinenbau- u. Hütten-schule in Duisburg. Halle a. S. Verlag von Wilhelm Knapp. 1897.

The electric furnace has given the metallurgist a means whereby many problems hitherto impossible of solution may be successfully attacked. It has revealed many entirely new and unsuspected facts in connection with the chemical behavior of substances at extremely high temperatures. It has given to the arts practically an entirely new class of compounds, the metallic carbides, possessed of extremely valuable properties; and when we shall have attained to a more thorough knowledge of the conditions under which the most efficient results may be realized, it will doubtless bring about a revolutionary change in many branches of the metallurgical arts.

In the present volume the author illustrates and describes the various forms of such furnaces that possess distinctive features of originality, and the investigator seeking for information on the subject will find it an extremely useful compendium for his purpose. W.

Theorie u. Praxis der Analytischen Elektrolyse der Metalle. Von Dr. Phil. Bernhard Neumann, Asst. für Hüttenkunde an der königl. techn. Hochschule zu Aachen. Halle a. S. Verlag von Wilhelm Knapp. 1897.

The application of the electrolytic method for the quantitative analytical determination of metals has been treated of in several publications devoted specially to the subject. The most important of these are the works of Classen and Smith, with both of which analytical chemists generally are familiar.

They have proved most useful in familiarizing chemists with merits of the electrolytic method, which has now come to be regarded not merely as a useful alternative in many analytical separations, but in fact an advantageous substitute for the older standard gravimetric and volumetric methods. The works above named, however, emanating as they do from the pioneer investigators in this field, have naturally enough been restricted, to a large extent, to the methods devised by their authors. The numerous recent contributions to this branch of analytical chemistry, however, make it most desirable that the student and investigator should have at command a more comprehensive work of the class.

The author of the work herewith noticed has endeavored to supplement the work of his predecessors by incorporating therein all the latest and most approved methods of electrolytic analysis, and especially those which have been found to be of technical importance.

He has also endeavored to improve upon the descriptive methods of Classen and Smith by indicating more or less exactly the current strength, voltage, temperature and other conditions essential for attaining the best results. W.

Theatre Fires and Panics: their causes and prevention. By William Paul Gerhard, C.E. New York: John Wiley & Sons. London: Chapman & Hall, Ltd. 1896.

The great amount of attention that has, of late years, been given to the subject of this volume, has had a most beneficial effect in doing away entirely with some of the most serious elements of danger in connection with theatre construction and internal arrangement, and in greatly diminishing the risk from others. Nevertheless, despite the most anxious considerations of the fire underwriters' experts, and the wholesome influence of more stringent municipal ordinances, it still remains unquestioned that the circumstances inseparably connected with the operations of the play-house are such as to render the making of it a thoroughly safe place of resort a matter of extreme difficulty, if it be not really impossible.

Every contribution to the subject of the causes and prevention of theatre fires from expert sources should be welcomed, and where, as in the case of this book, the author makes many sound and sensible suggestions for the lessening of the fire hazard in theatre buildings, and the dangers to life, the work can do much good. W.

The Chronicle Fire Tables for 1897. New York: The Chronicle Company, Ltd. 1897. (Price, $).

We need only say, in connection with these statistical tables, that they are as carefully elaborated and as thorough as those of the previous yearly publications, which have gained for the Chronicle Fire Tables their excellent reputation among fire underwriters.

The tables exhibit some singular facts which would seem to justify the statement in the book that "there is nothing so uncertain as the yearly fire loss." For example, while the number of fires and the number of risks burned increased by thousands (being 61,133 in 1896, as compared with 53,961 in 1895), both the fire and insurance loss fell below the loss of 1895 by millions.

The total fire loss in the United States in 1896 was $118,000,000, or $24,000,000 less than that of 1895, and the insurance loss in 1896 was $31,316,560 as compared with $37,800,440 in 1895. W.

The Watch and Clock Makers' Hand-Book, Dictionary and Guide. By J. F. Britten. Ninth Edition. London: E. & F. N. Spon. New York: Spon & Chamberlain. 1896.

This work is one of the most useful hand-books for the craft in the English language, and the appearance of a ninth edition is good evidence that its utility continues undiminished. An excellent part of the dictionary feature is the addition to the technical terms, of their French and German equivalents, which is a decided advantage to those who use the work for reference. W.

Fuels and Refractory Materials. By A. Humboldt Sexton, F.I.C., F.C.S., etc. London: Blackie & Son, Ltd. 1897.

The object sought by the author in the present work was to prepare a

manual dealing concisely, though comprehensively, with the subject of fuel, and which should hold a place between the exhaustive treatises of Dr. Percy, Dr. Mills and Mr. Rowan, and such brief outlines of the subject as are to be found in the manuals of metallurgy, so as to adapt it specially to the needs of students and incidentally also to engineers.

The various chapters deal with combustion, fuels—solid, liquid and gaseous—their preparation; by-products and their recovery; metallurgical furnaces; air supply to furnaces; removal of waste products; smoke and smoke prevention; pyrometry, calorimetry, utilization and testing of fuels; refractory materials, bricks, crucibles, etc.

The arrangement of the subjects considered and the manner of treatment, are most satisfactory, and the value of the work is substantially aided by the number and excellence of the illustrations. W.

The Tutorial Chemistry. Part I. Non-Metals. By G. H. Bailey, D.S.C. (Lond.), Ph.D. (Heidelberg). Edited by William Briggs, M.A., F.C.S., F.R.A.S. London: University Correspondence College Press. Hinds & Noble New York. [n. d.]

This volume forms one of "The University Tutorial Series" prepared for the special use of teacher and student. The subject is, therefore, treated with the object in view of carrying the experimental method of verification along with the statement of the fundamental facts of the science, so that the student may be trained in the scientific method of observation and inferences as he progresses.

The book offers a well-arranged treatise for teaching the elements of chemistry. W.

The Designing and Construction of Storage Reservoirs. By Arthur Jacobs, B.A. Second American Edition, revised and extended by E. Sherman Gould, M. Am. Soc. C. E. New York: D. Van Nostrand Company. 1897. Price, 50 cents.

The present revised American edition of this well-known standard treatise bears evidence of having received the careful attention of the American editor in the form of numerous changes in, and additions to, the editorial notes and remarks which usefully supplement the original text and bring the subject up to date. W.

Encyclopédie scientifique des Aide-Memoire. Librairie Gauthier-Villars et Fils. Paris. 1897.

Two volumes of this work have appeared since our latest notice, viz.:

Electromoteurs et leur applications. Par Georges Dumont, Vice-President de la Société des Ingenieurs Civils de France, etc. (Small 8vo, 2.50 francs unbound; 3 francs bound.)

In this volume the author discusses, first, the various systems of power distribution in vogue in factories and workshops, and passes to the study of electric motors and electric transmission. The author concludes with some judicious considerations of the comparative merits of the electric and

mechanical systems of power transmission, and with a review of the principal applications of the electric motor.

Les Transformateurs de Tension en Courants Alternatifs. Par F. Loppé, Ingenieur des Arts et Mfrs. (Small 8vo, 2.50 francs, unbound; 3 francs bound).

This brochure is divided into two parts. In the first, the author deals concisely with the important theoretical question involved in the subject. In the second he treats of the use of transformers, their classification, the calculation of dimensions of an apparatus to fulfil given conditions, and to the description of the principal types of transformers, single and polyphase currents.

W.

The Materials of Construction: A Treatise for Engineers on the Strength of Materials. By J. B. Johnson, C.E., etc. New York: John Wiley & Sons. London: Chapman & Hall, Ltd. 1897. Royal 8vo. Pp. 787. Price, $6.

The author has placed at the service of the engineering fraternity a comprehensive treatise on the strength of materials used in construction, in which he has incorporated the most important data derived from recent extensive contributions to scientific testing methods abroad and at home.

The subject is treated under four general heads, viz.: Part I treats of "The Principles of Mechanics Underlying the Laws of the Strength of Materials;" Part II describes the "Manufacture and General Properties of the Materials of Construction;" Part III deals with "Testing Machines and Methods of Testing Materials of Construction; Part IV treats of the "Mechanical Properties of the Materials of Construction, as Revealed by Actual Tests." Several appendices follow.

Of the special features of the work, we have space only to notice the unusual use which the author has made of the stress diagrams and other graphical methods of representing facts and laws, to the corresponding exclusion of data arranged in tabular form. This idea has been consistently carried through the work, and has the obvious merit of impressing on the reader ideas of relationships more profoundly than the mere expression of results in the form of tables. The author also has used throughout the work, in diagrams and text, the English units of weights and measures (pound and inch) on the reasonable plea that "until the metric system has been definitely adopted it is best to use the old units, and that a double system of units is confusing."

An innovation, somewhat radical, though unquestionably meritorious, is the author's adoption of a "new elastic limit," which he proposes to the profession for general adoption.

The work is a highly meritorious contribution to engineering literature, and will, doubtless, receive a warm welcome from the profession.

The publishers have printed and illustrated the book in their usual excellent style.

W.